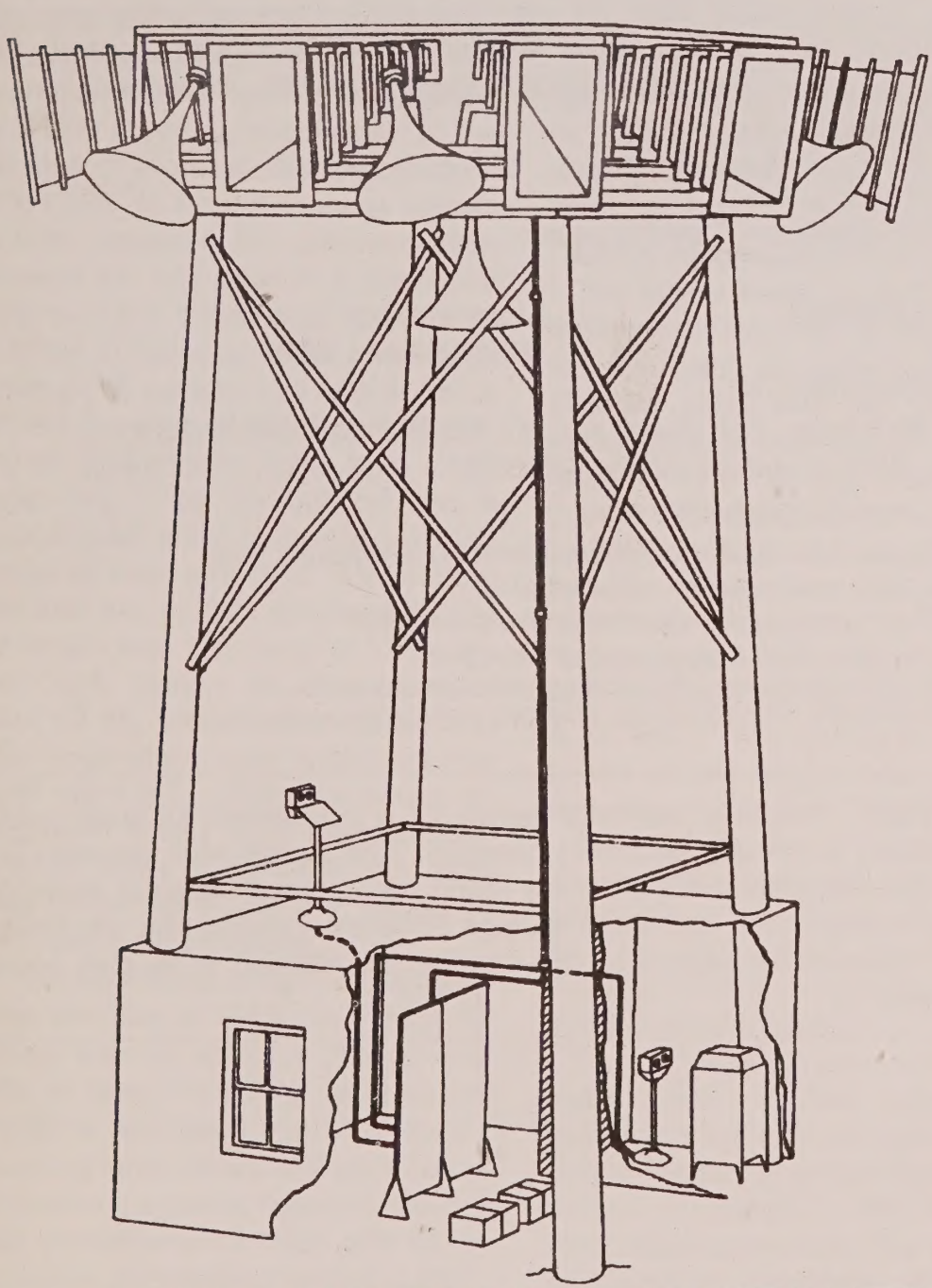
Tube Collectors Association
Special Publication No. 18

PUBLIC ADDRESS SYSTEMS
1922 AT&T BULLETIN



DRAWING 144-A-63. TYPICAL OUTDOOR INSTALLATION - LONG LINE RECEIVING, CONTROL ROOM UNDER PLATFORM

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THE COVER: This is a mid-1922 design for a permanent, full-scale public-address system to cover large events outdoors. The square horn speakers provide long-distance projection, while the round horns handle close-in coverage. Two racks of equipment and some storage batteries comprise the electronics. Recorded music is available from the cranked phonograph in its own sound-isolation room.

TCA INTRODUCTION

Public address systems were the first venture of the Western Electric Company into professional audio, long before radio broadcasting, electrical disc recording, or motion-picture sound. This AT&T bulletin details the "state of the art" as of 1922, some years after development began.

The effort started before tube amplifiers were practical. The basis was an oversized double-button carbon microphone directly feeding loudspeakers ("loud speaking telephones" in the parlance of the day), first demonstrated in 1908. In 1912 a one-way system became available for communication between the test desk in a telephone office and the distributing frame, later modified to two-way. The initial long-distance PA system trial was in 1913, with the governor of Oklahoma addressing an audience in Tulsa from Oklahoma City. The microphone was a water-cooled affair operating with DC current of three amperes. It is remarkable that this system succeeded: the line facility was 122 miles of 12-gauge open wire, having an attenuation of about 10 dB, but entrance cables and local loops must have added another six or eight dB. (This high-power arrangement would have been troublesome in terms of crosstalk into other wires on the same pole line, the power levels being very different.)

A demonstration system using tubes came into play in 1916. In 1919 a PA system was set up for a Victory Loan drive in New York City, with several amplifiers and more than 100 speakers along three blocks of Park Avenue.

WE sound systems figured in the political conventions of 1920 and the inauguration of President Harding in 1921.

The burial of the Unknown Soldier at Arlington National Cemetery in 1921 involved a multi-system reaching 100,000 people on-site, 30,000 at Madison Square Garden in New York, and 20,000 in and outside the Civic Auditorium in San Francisco. It used 80 speakers and 3900 miles of telephone line, not counting Morse order wires and diverse-routed backup lines.

A two-way system enabled a joint meeting of the Institute of Radio Engineers in February, 1923, with 500 members in Chicago and 1000 in New York.

The AT&T bulletin talks in terms of use of only carbon microphones, but by 1923 a condenser mic and preamp were in use for music programming and other higher-quality uses.

"MILES ABOVE ZERO LEVEL"

The unit of electrical loss or gain at the time was the "mile of standard cable," this being an early type of long-distance cable with No. 19 wire (88 ohms per loop mile) and shunt capacitance of 0.054 μF per mile. The frequency of measurement was defined as 796 Hz (5000 radians per second), usually rounded to 800 Hz. (The "mile" was replaced by the logarithmic "transmission unit" in 1925, which was later renamed the decibel in honor of A. G. Bell.) The standard cable gave a loss of one dB per mile at 890 Hz and about 1.06 dB at 1000 Hz.

As an aside, the influence of Western Electric engineers on tube development is reflected in the Signal Corps SCR-81 "Set, Field Vacuum Tube Testing" of WW I, which "reads directly in miles amplification."

The concept of "zero level" was originally defined as "the output from a standard telephone set connected to a common-battery central office by a line of zero resistance." This is a somewhat slippery concept. The sound and broadcasting industries standardized "zero level" as one milliwatt across 600 ohms in 1939. However, there was an earlier figure of 6 mW in 500 ohms, and values before then of 10 and 12.5

mW in 500 ohms.

It would be of interest to determine which "zero level" was involved in the 1922 systems. Additionally, it would be helpful to find out the power outputs of the power amplifiers. These are not given directly in the AT&T bulletin. However, a *BSTJ* article gives such figures. To summarize the various amplifiers and their nomenclature, they were:

8-A, "A," ex-D-76527; high-gain speech amp
9-A, "B," D-76529; medium-level power amp, 4 W ("+30 miles") out
10-A, "C," D-76562; high-level power amp, 40 W ("+40 miles") out
11-A, "D"; low-gain speech amp

The AT&T/WE engineers evidently considered a "mile" to equal a decibel for their purposes. That would make "zero level" about four milliwatts in 500 ohms.

The amplifiers were available when the need for speech-input equipment for broadcasting arose. The 8-A was developed into the 8-B and 8-C. The 9-A was unchanged. The 10-A evidently inspired the design of the 43-A theater amplifier of ca. 1929, although two of the four 211-type tubes were reassigned to a built-in power supply.

TUBE TYPES

Several of the tubes ("repeater bulbs") in this equipment carry numbers that are unfamiliar today, even to WECo enthusiasts. They and their more common equivalents were:

105-A power triode, a 205-type with "commercial" markings.

113-A power triode, a 211A with "commercial" markings.

D-76622 rectifier, a gridless 212A.

A DETAIL: PIN NUMBERING

Inspection of the diagram of the 8-A amplifier reveals that the filament pins were numbered "2" and "3." This predates the later General Electric / RCA / Western Electric plan, in which the filament, no matter how many pins the base contained, was always on "3" and "4." It also differs from the Radio Manufacturers Association 1933 plan which all three makers adopted and with which we are familiar today. The filament pins are numbered the same way ("2" and "3") on the 214-A sockets used in the 7-A small PA amplifier of about the same vintage.

ANOTHER DETAIL: "OHMS"

A look at the circuit diagrams reveals the traditional telephone-industry practice of designating a resistor in the "ohms" range with a lower-case omega (ω) and one in the megohms area with upper-case (Ω). The Stromberg-Carlson Telephone Manufacturing Co. did the same on its '20s radio diagrams. The Kellogg Switchboard and Supply Co. used "ω" and "MEG" on its.

THE COMPETITIVE PICTURE

These early systems were pioneering work. About the only competing manufacturer was relatively tiny Magnavox, in California, which had essentially no access to the Bell telephone company market. Ten years later, however, the huge advances in electronics had made it possible for new firms to enter the PA market: De Forest, Samson, Jenkins and Adair, Webster Electric, RCA Victor, Kenyon, and so on. WECo faded out of this product line.

At least some telephone companies filed tariffs to provide PA systems. As late at the '70s, Pacific Telephone owned and maintained the extensive system at the San Francisco International Airport. - LAS

CAVEAT

The AT&T bulletin that follows has been reformatted from 8-½" x 11" size, typed double-spaced. It is not an exact copy as regards the line drawings. These have had graphic elements moved about to improve readability in the face of size reduction. Most of the

original lettering, which was small and smudged, has been replaced with computer-generated characters.

ACKNOWLEDGEMENT

To Frank Hagenbuch, who furnished the original manuscript and scans of the photos.

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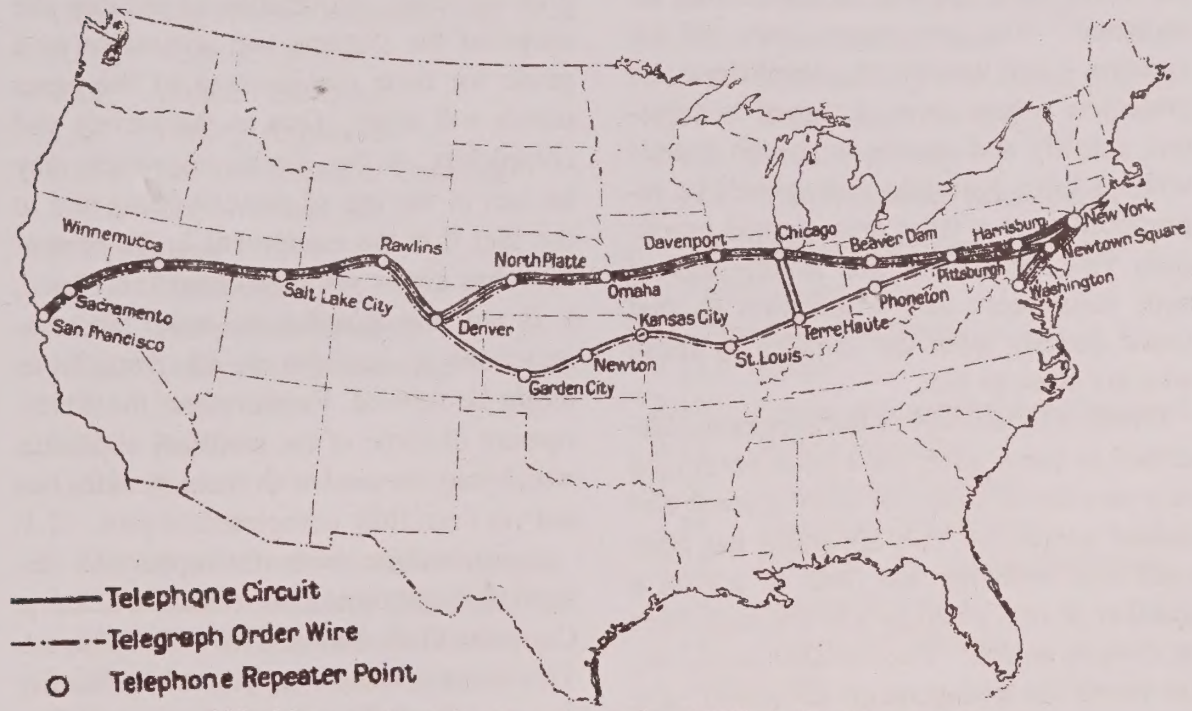

Working and protection lines for 1921 Arlington event.

Source: BSTJ, *April 1923*

AMERICAN TELEPHONE AND TELEGRAPH COMPANY
Department of Development and Research

PUBLIC ADDRESS SYSTEMS

Preliminary Notes

Approved:
J. J. Carty
Vice President

The accompanying Preliminary Notes on "Public Address Systems" describe the systems which have been developed to provide means of extending the range of the voice of a speaker in addressing an audience. The component parts of the systems - the transmitter, amplifiers and projectors - have been designed to transmit, amplify and distribute speech sounds with so little distortion that speech so reproduced over a large area sounds practically the same from the standpoints of both naturalness and articulation as that heard directly from the speaker by those who are close to him.

Preliminary models of the apparatus described in these notes have been employed in a number of cases for both outdoor and indoor audiences. This apparatus has been used also with the toll lines to permit a speaker at one place to address audiences at distant points. Two notable occasions on which the arrangements described have been used with great success are the inauguration on March 4, 1921, when 125,000 people at the Capitol in Washington heard President Harding's address; and the Armistice Day Services on November 11, 1921, when the speeches and music at Arlington Cemetery were heard by 100,000 people at the cemetery, 35,000 people indoors and outdoors in New York, and 20,000 people indoors and outdoors at San Francisco.

The notes describe the equipment which has been recently standardized for the public address systems, outline some of their uses, and give instructions regarding their application and operation. While the notes will, therefore, require modifications and extensions in some particulars, they give sufficient information to indicate the scope of the systems and will serve as a guide for their use in most of the cases which will arise. Due to the variety and complexity of the conditions which may be met in the use of these systems and to the fact that the equipment in its present form has not as yet been extensively used, it is not now possible to make these instructions as definite in all respects as might be desired. Furthermore, the development of some of the auxiliary apparatus which may be used with these systems has not yet been fully completed.

In connection with the apparatus described in the notes, the Western Electric Company Bulletin No. T-672 is of interest. This bulletin, which was prepared primarily for the sale of this apparatus outside of the Bell System, has already been distributed to the Associated Companies through the regular channels for such material.

Note: Both in the text and on the drawings Western Electric specification numbers are given in certain cases instead of code numbers. Also, on some of the drawings the old terminology of A, B, C and D amplifiers has been used in place of the respective code numbers 8-A, 9-A, 10-A and 11-A. Wherever available the proper code numbers should preferably be used, both in ordering and speaking of apparatus.

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PRELIMINARY NOTES ON PUBLIC ADDRESS SYSTEMS

0. GENERAL

0.1 Introduction and Uses

The Public Address Systems described in these notes were developed to provide a means of so greatly amplifying the voice of a speaker that it could be easily understood by and would sound natural to everyone in any size of audience that could be gathered together.

This requires (A) picking up some of the sound from the speaker's voice without unduly restricting his usual actions, (B) enormously amplifying the power so picked up, and (C) properly directing and controlling the amplified sounds so as to deliver sufficient volume to all the outlying parts of the audience without interfering with the nearby portion of the audience which normally hear the speaker directly. All of this collecting, amplifying, and directing must be carried out with practically no recognizable distortion in the reproduced speech sounds.

For picking up the speaker's voice, use is made of a specially constructed carbon-button microphone whose efficiency is approximately the same for all the frequencies in the voice range. The amplification is obtained with multistage vacuum-tube amplifiers actuating loud-speaking receivers capable of handling relatively large amounts of power. The directing of the reproduced sounds is accomplished by projectors or horns which are coupled to these receivers. These projectors are usually arranged over the speaker's head and are directed so that the sounds from them will appear to come from the speaker. In the design of the component parts of these systems particular attention has been given to providing apparatus which will have its reproduction efficiency as nearly uniform as practicable for the frequency range involved in speech.

These systems are applicable not only for large outdoor audiences but also for indoor locations such as halls and. armories where the audience can not normally hear the speaker sufficiently well. As brought out later, special consideration must be given to the acoustical conditions of the places where these systems are used and provision made for these conditions in order to obtain good results. This is particularly important for indoor locations which, in general, have not been designed for properly handling the amount of sound which the system is capable of providing.

A natural extension of the above applications of these systems is the use of them in connection with the telephone toll lines to permit a speaker in one place to address an audience at another place, the audience being either outdoors or indoors. Also, by connecting by toll lines public address systems at two or more places, a speaker may address large audiences at a number of points.

The public address systems have been used in a considerable number of cases to amplify the volume of music, either vocal or instrumental, or from a phonograph record. As music may involve a much wider frequency range than speech, the requirements for the proper transmission of music may be much more severe. It is difficult to make general statements as to the capabilities of these systems for handling music, since the conditions both as to the character of the music and as to the needs of the audience, vary tremendously. In general, however, it can be said that a simple vocal solo not involving the low bass notes will carry sufficiently well over such a system as to be pleasing to the usual audience. Likewise, an instrumental solo in the same frequency range, such as a violin solo which does not involve notes of too high frequency will also be satisfactory. On the other hand, these systems will not,

in general, be suitable for amplifying or transmitting to distant points the music from a symphony orchestra. Particularly will this be true where the audience is made up of people who are highly appreciative of good music, and are therefore critical with respect to it. Between these two extremes judgment must be used as to what is and what is not a proper use to make of this apparatus. In any case, a trial should be made if possible of the music which it is desired to transmit over these systems to determine whether the results obtained are suitable. This trial can also be used to place and properly instruct those who are to furnish the music. When the music comes from a number of sources such as in the case of a quartet or an orchestra, tests should be made to determine the location of the transmitter so as to pick up the various parts with proper relative magnitudes.

These systems make it possible for a speaker to address successfully enormous outdoor audiences. They have been used for crowds of over 100,000 people, some of whom were over 1000 feet from the speaker. In indoor places they have been employed for a crowd of 15,000 people. By connecting together a number of systems, any number of people can be addressed at one time.

0.2 Typical Layouts

It is not possible to give complete information for the use of the Public Address Systems which will directly apply in every instance. Each case will require more or less individual treatment in the way of layout and arrangement of apparatus, depending on the facilities available and acoustic conditions. Such considerations as would tend to modify or change the arrangements here shown are dealt with later.

The accompanying drawings and photographs show the general arrangements and combinations of apparatus which should prove most satisfactory. They are given only as generally typical of conditions which may be met.

0.21. Outdoor Local Installations

The simplest form of installation is one where a local speaker addresses a large audience in the open air with no long-line connections, either incoming or outgoing, to distant points. In this case the audience may be grouped on all sides of the speaker or may be in front and to the sides only. Complications may of course be introduced by buildings, foliage or uneven ground, which will require special precautions in the grouping and arrangement of apparatus. Such precautions are discussed more fully hereafter.

Drawings Nos. 144-A-53 and 144-A-54 show schematic arrangements of the apparatus in general required for an installation of this type. The four combinations given will take care of cases where either large or medium power is required, providing in each case for the speaker talking either close to the transmitter, as where announcements only are to be made, or several feet from it, where freedom of movement is desired.

In general, the C-type amplifier will be required for an outdoor installation. The B-type amplifier may, however, furnish sufficient power for quite small outdoor audiences, unless acoustic conditions are exceptionally bad.

Drawing No. 144-A-55 shows in perspective an outdoor installation where the audience would be grouped on all sides of the speaker in the open air. The control room is shown under the speaker's platform. This location, as noted later, is desirable, since the wiring to the transmitters and projectors is short, easy to conceal, and free from possible interference troubles.

Drawing No. 144-A-56 shows an installation where the speaker's stand is on the steps of a building, the control room being in the basement, and the audience in front and to either side of the speaker. Interfering buildings are shown, illustrating the placing of projectors to avoid trouble from echo.

This drawing also illustrates a situation where it might be impossible to reach all

of the audience by one group of projectors because of intervening obstructions such as the building shown. Particular care must be taken in a case of this kind in placing the projectors that the sounds emitted from one source do not interfere with those from the other. This matter is discussed further in Section 1.3, Acoustics.

Plate No. 1 gives photographs of actual installations that have been made, showing three typical structures for the speaker's stand and projector's support.

Figure 1 illustrates a structural iron mounting for the projectors and the use of a portable garage for a control room. In this case the audience was all in front of the speaker.

Figure 2 illustrates the use of telephone poles for the projector support. In this case it was desired to cover the ground on all sides of the speaker.

Figure 3 shows a somewhat more finished structure than in the other two cases, and illustrates what may be done with fairly simple materials in the way of concealing the projectors. In this case the control room is built into the base of the stand. Here also the audience was on all sides of the speaker.

0.22 Indoor Local Installations

Drawings Nos. 144-A-57 and 144-A-58 give schematics of the arrangement of apparatus for both close and distant talking, in the case of an indoor installation only, and a combined indoor and outdoor installation.

Drawings Nos. 144-A-59 and 144-A-60 are typical of indoor installations, the first showing the speaker's platform in the center of the building, and the second illustrating it at one end.

Plate No. 2 illustrates three indoor installations that have been made, and shows typical means for supporting projectors. These installations were, in all cases, in large auditoriums and make use of the No. 5-A horn. For the greater number of indoor installations, the smaller 6-A or 7-A horns will be satisfactory and are considerably easier to support. They are, however, mounted in clusters as shown in the photograph and supported in the same general way as with the 5-A horns.

0.23 Long Lines Connections

Very frequently it is desired to connect by means of long lines to a distant point, either that an audience at the far end may hear the local speaker, or that a distant speaker may talk to the local audience. Provision is made for these features in the Public Address Systems, and they are more fully discussed in Section 1.4, Long Lines Service.

Drawings Nos. 144-A-61 and 144-A-62 show schematically the arrangement of apparatus for simple one-way service with long line receiving or transmitting in addition to the local performance.

Drawing No. 144-A-63 shows a typical outdoor installation with long line receiving. Comparing this with Drawing No. 144-A-65, it should be noted that the only essential difference in local apparatus is the addition of a group of projectors to cover the speaker's platform and the area reached by the local speaker's voice directly.

1. TECHNICAL DESCRIPTION

1.1 Transmission

The various units comprising the Public Address System have been designed so as to fit together with a minimum amount of reflection losses and to be as flexible as possible so as to meet the different types of service required of them. The amplifiers have been designed with a view of obtaining as flat transmission frequency characteristics as possible.

On Drawing No. 906-867 is [sic] shown in schematic form combinations of the various units which may occur with different types of service, together with the energy levels involved. Figure 1 shows the arrangement for complete local service with transmission to the long lines. The power put out by the transmitter for the distant-talking condition is about 70 miles below the zero level. The weak currents are carried through the transmitter-control

panel to the input of the transmitter amplifier where they are amplified and the output voltage of this amplifier is impressed on the input circuit of the power amplifier which further amplifies the received transmission. The maximum output of the power amplifier may be either +30 miles or +40 miles, depending upon the type of power unit used. The output from the power amplifier is applied to the volume-control panel which consists of a means for supplying the required amount of power to the various projectors. A volume indicator, as shown, is connected to the volume-control panel and is used to assist the operator in maintaining constant-volume output from the projectors. Transmission is supplied to the loop connected to the Long Lines circuit through the volume control panel as shown at a level of about +10 miles. Zero level should, in general, be supplied to the Long Lines circuit at the toll test board.

Figure 2 shows the arrangement where the transmitting and receiving amplifiers are at different points. At station "A" either the close-talking or distant-talking transmitter may be used. For the close-talking condition the power output of the transmitter is about 20 miles below the zero level. This requires the use of an amplifier of moderate gain only. As in the condition mentioned above, the output currents of the transmitter are passed through the transmitter-control panel to the input of the transmitter amplifier where they are amplified and sent out on the Long Lines circuit at a power level of +10 miles. At station "B" the power received from the long lines is applied, to the input of the 11-A amplifier, where it is amplified and the output of this amplifier is impressed on the input of the power unit in the same manner as explained for Figure 1. This type of service requires that the equivalent of the Long Lines circuit be such that the received transmission is at a power level not lower than -15 miles.

1.11 Transmitters

The transmitters (No. 369-W) which are used in the system have been designed to introduce practically no distortion for the range of frequencies required for good reproduction of speech. They represent in this respect a material advance on the transmitters ordinarily used in telephone service but which are less efficient from the standpoint of volume. The diaphragm of this transmitter is stretched so as to have its natural frequency above the range of frequencies encountered in speech and is supported very close to a fixed metal plate so that the thin film of air between the diaphragm and the plate serves to dampen the motion of the diaphragm. Two carbon buttons are used, one on each side of the diaphragm, connected so that the distortion in one button will be counteracted by that in the other. This arrangement is known as a "push-pull" transmitter. No collecting horn or mouthpiece is used on the transmitter.

By these means a high-quality transmitter has been obtained which permits a reproduction of the speech sounds which is very close to the original. The volume efficiency of the transmitter is, however, considerably lower than that of the transmitters used in substation sets. For close talking, the high-quality transmitter puts out power which is about thirty miles below that delivered by the standard telephone substation set on zero loop to the trunk. For reference, the output of this set is called here the “zero level.” For talking five feet away from the high-quality transmitter, its output is about seventy miles below this zero level.

The resistance of each button is about 100 ohms, and as the two are effectively in series for the telephone currents, the transmitter should work into an impedance of 200 ohms.

Details of the transmitter are shown on Drawing No. 197-B-22 and on Plates 3 and 4.

Another type of high-quality transmitter is being developed for use with close talking. This transmitter will be somewhat lighter and probably about 10 miles more efficient.

1.12 Projectors

Each projector consists of a No. 196-W loud speaking receiver with the necessary mounting and a horn. The loud-speaking receiver is a special type of telephone receiver designed to carry large amounts of power with small distortion and maximum efficiency. The diaphragm is made of a corrugated impregnated cloth which permits vibrations of a large amplitude. This diaphragm is connected to the armature by a light connecting link. The armature is mounted between the pole pieces of a permanent magnet and is surrounded by the winding carrying the voice currents. These features are shown schematically on Plate 10 and the physical appearance of the receiver is shown on Plates 11 and 12. When equipped with a ten-foot horn, a single receiver will carry without serious distortion or overheating power which is about 34 miles above zero level. For covering extremely long distance, higher power may be used, but for this purpose the receivers should be tested and those chosen which will not rattle.

The impedance of the receiver at 1000 cycles is about 2300 ohms at a positive angle of 60 degrees.

The receivers are provided with horns of various shapes, the choice of which depends on the distribution of sound which is desired, as described in a later division of this bulletin. One object of the horn is to direct the sound so as to give the desired distribution. A second is to effectively connect the diaphragm to the air that is to make the vibration of the diaphragm set in motion a large volume of air.

1.13 Amplifiers

The amplifier units for the Public Address System consist of four different types. The No. 8-A amplifier is a unit arranged for use with the distant-talking transmitter. It has a gain range of 22 to 85 miles in steps of 3 miles and has a power capacity of about +10 or +20 miles above the zero level, depending on whether 130 or 350 volts are applied to the plate circuit of the last tube. Its output impedance is 500 ohms. Its input impedance is 200 ohms. For local service this amplifier is required, connected ahead of either of the power amplifiers, although there may be cases where only a small amount of power is required, in which case the 8-A amplifier can be used alone. This amplifier may also be used connected directly to a Long Lines circuit.

The No. 11-A amplifier is also a transmitter amplifier for use with a close-talking transmitter. This amplifier has a gain range of -1 to 30 miles in 2-mile steps and can handle the same power levels as the No. 8-A unit. This amplifier has a second function in that it can be used as a receiving amplifier in front of the power amplifiers when connection is made to a Long Lines circuit. The input impedance of this amplifier is 200 ohms for the transmitter connection and 500 ohms for the connection to the long lines. Its output impedance is 500 ohms.

The No. 9-A amplifier is a moderate-power amplifier designed primarily for indoor use. This amplifier increases the gain of either the No. 8-A or 11-A amplifiers about 15 miles and has a power capacity of about 30 miles above zero. Its output impedance is 500 ohms.

The No. 10-A amplifier is a high-power amplifier designed primarily for outdoor use. This amplifier is arranged to work with either the No. 8-A or 11-A amplifiers and increases the gain of either of these amplifiers about 25 miles and has a power capacity of 40 miles above zero. Its output impedance is 500 ohms. A more detailed discussion regarding the transmission features of these amplifiers follows:

1.131 Transmitter Amplifier No. 8-A. On Drawing No. 906-583 is shown in schematic form the transmission circuit of the No. 8-A amplifier. This amplifier consists of three stages, the first two stages employing type 102-D tubes and the third stage employing a 105-A type tube. Care has been taken in the design of this amplifier to obtain good transmission frequency

fier to obtain good transmission frequency characteristics from frequencies as low as 60 cycles up to 5,000 cycles. This requires special arrangements such as a special input transformer as shown and two retard coils in series with the battery supply for the plate circuits of each 102-type tube. The grid potential is supplied to these tubes by means of the potential drop in a small resistance as shown. This amplifier is designed for use either with 130-volt or 350-volt supply. When the amplifier is used connected to a Long Lines circuit, 130 volts may be supplied for the plate potential. When the amplifier is used connected to either of the two power amplifiers, 350 volts should be applied to the plate circuit of the last tube. As shown on the drawing, a potentiometer is included in the plate circuit supply when 350 volts are used in order to cut down the potential applied to the 102-type tubes to the proper value. Arrangement is made in the output circuit to cut out the output transformer when this amplifier is used either with the Nos. 9-A or 10-A amplifiers. By eliminating the output transformer and connecting the last stage directly to the input transformer of the power stage, the required alternating voltage on the grids of the power amplifier is obtained through a circuit of the lowest possible impedance. This enables the maximum power output to be obtained without appreciable distortion due to grid conductivity.

A 9-volt C battery is required when 130 volts is applied to the 105-A tube and a 22-½ volt C battery is required when 350 volts is used. In order to obtain the range of 22 to 85 miles, two potentiometers are required, the first potentiometer being a simple resistance with two taps shunted across the high side of the input transformer. The second potentiometer is connected between the two 102-type tubes as shown and has a gain range of 33 miles in 3-mile steps. On Drawing No. 905-675 this potentiometer is shown in detail. Other than the arrangements discussed above, no special features are involved in this amplifier.

1.132 Transmitter Amplifier No. 11-A. On Drawing No. 905-586 is shown in schematic form the transmission circuit of the No. 11-A amplifier. This is a single-stage unit employing a 105-A type tube. When this amplifier is used with its output connected directly to the Long Lines, the plate potential required is 130 volts, although 350 volts may be used if desired. When the amplifier is connected either to the No. 9-A or 10-A amplifiers, 350 volts should be used for the plate potential. The input circuit is arranged for connection either to a transmitter as shown or to a Long Lines circuit. The potentiometer has a 13-mile range in 2-mile steps. On Drawing No. 906-872 this potentiometer is shown in detail. The high side of the input coil is provided with two taps in order to extend the gain range of this amplifier. A grid potential of 9 volts is required for use when 130-volt supply is used and 22-½ volts when 350 volts are applied to the plate circuit. As shown, the output coil of this amplifier is arranged to be cut out the same as in the No. 8-A amplifier when connection is made either to the No. 9-A or 10-A amplifiers.

1.133 Medium Power Amplifier No. 9-A. On Drawing No. 906–584 is shown a schematic diagram of the No. 9-A amplifier. Since this amplifier is required to handle larger power capacity than either the No. 8-A or 11-A units, it is necessary to employ two No. 105-A tubes arranged in a push-pull circuit operating at 350 volts. The grid potential required is 22-½ volts. The output impedance is 300 ohms. The input of this amplifier is arranged for connection to the plate circuit of either the No. 8-A or 11-A units. No gain adjustments are provided on this amplifier.

1.134 High Power Amplifier No. 10-A. On Drawing No. 906-585 is shown in schematic form the No. 10-A amplifier. In order to handle the very large amounts of power required from this amplifier, four No. 113-A type tubes have been used arranged in a parallel push–pull circuit oper-

ating at 750 volts. Its output impedance is 500 ohms. The input of this amplifier is arranged for connection to the plate circuit of either the No. 8–A or 11–A units.

Note: Due to difficulties in coil manufacture it has not been possible to equip initially the Nos. 9-A and 10-A amplifiers with the input coil shown on Drawings Nos. 906-584 and 906-565 respectively. Instead a D-76523 input transformer having an impedance ratio of 4000 to 30,000 has been used, with 4000 ohms shunted across the low side. The gain characteristic with this arrangement is practically the same as will be obtained with the new coil. The maximum power which the power amplifiers equipped with D-76525 transformers will handle is several miles below their rated capacities as stated elsewhere in these notes.

1.135 Volume Control. To regulate the volume applied to the different projectors, a special autotransformer with several taps is employed, which is connected across the output of the power amplifiers. This arrangement is shown schematically on Drawing No. 906-862. The coil has a sufficiently high impedance so as not to affect the transmission-frequency characteristic of the system to any marked degree. One side of all the receiver leads is connected in common to one side of the coil. The other side of the receiver leads is connected through a dial switch so contact may be made as desired to any tap of the autotransformer. The output voltage of the amplifier is impressed on the autotransformer and the taps are so arranged that there is a voltage difference between each pair of taps corresponding to a transmission difference of two miles. The total volume range is 20 miles.

As shown on Drawing No. 906-862, three terminals marked "C," "H," and "L" are provided for connection to the volume indicator. The purpose of this connection will be explained in division 1.14. The power level across terminals "C" "H" is 20 miles lower than across terminals "C" "L."

Where it is necessary to realize the full output of the amplifiers, the load connected should have approximately the same impedance as that of the amplifier. Because of the way in which the projectors are connected, it is much more convenient to work with admittances in calculating the joint effect than with impedances. The admittance of the amplifier is 1 / 500 = .002 mhos, or two millimhos. With a given grouping of the projectors, the admittance of the combination can be determined. If it is between 1 and 4 millimhos, which corresponds to an impedance between 1000 and 250 ohms, no readjustment will be required. The following method may be used to determine the total admittance of the load:

The admittance of a single projector is 0.5 millimhos. Connected to any tap of the autotransformer, it takes the same power from the amplifier as an admittance of 0.5 F millimhos connected directly to the amplifier terminals. "F" is the admittance factor corresponding to the power ratio of the miles change for the different steps on the autotransformer and its value for the dial readings are given in the following table.

Dial Setting	0	2	4	6	8	10	12	14	16	18	20
Miles Change	0	2	4	6	8	10	12	14	16	18	20
Factor F	1	.647	.418	.270	.1748	.113	.073	.0474	.0305	.01984	.012

If n projectors are connected to the same tap, the equivalent admittance at the amplifier terminals is Y = 0.5 n F for the group. The joint equivalent admittance is the sum of the equivalent admittances for all occupied taps, that is, $Y_0 = Y_1 + Y_2 + Y_3$, etc.

If Y_0 is greater than 4, or less than 1, millimho, it may be brought within the limits by shifting all groups up or down the same number of steps on the autotransformer, without changing the relative levels of

the different groups. Shifting all groups to the next lower numbered step multiplies the joint equivalent admittance by a value of F coresponding to 2 miles, 2 steps by the value corresponding to 4 miles, etc. Shifting all groups to the next higher numbered step divides the joint equivalent admittance by the value of F corresponding to 2 miles, 2 steps by the value corresponding to 4 miles, etc.

For example, should $Y_0 = 10$ millimhos, it means that its value should be multiplied by 0.2 to obtain the desired value for Y_0. Looking up on the table, the factor F, which is nearest 0.2, gives 8 miles as the number of miles which the entire group should be shifted downward to obtain the proper load impedance for the amplifier.

A single volume-control panel has 8 dials, including the dial for the monitoring projector, which has in series with the receiver leads 20,000 ohms to reduce the volume supplied to this receiver, since but a small amount of power is required. Any projectors not needing to be adjusted separately may be connected in parallel to the same dial. If more than seven projectors or seven groups of projectors are required, and it is necessary to regulate these groups independently, an additional volume-control panel can be used with the autotransformers in each volume control panel connected in parallel.

1.14 Volume Indicator

The volume indicator is a vacuum-tube detector device of such high impedance input that it causes negligible loss and negligible impedance irregularity when bridged on a telephone circuit. The plate current of the vacuum tube is indicated by a galvanometer whose deflections are, therefore, a measure of the alternating-current power in the circuit to which the indicator is connected.

A diagram of this volume indicator is shown on Drawing No. 906-673. An input coil with several taps is provided, thus enabling satisfactory indication to be obtained when the device is connected to circuits having different power levels. The coil has a range of 20 miles in 2-mile steps. A No. 102-D type tube is used as the detecting element. The grid potential applied to this tube can be adjusted by means of a potentiometer in the filament circuit in order to enable the tube to work on the most suitable part of its detector characteristic. The rectified current passes through a retard coil and the galvanometer circuit. The galvanometer has a 30-ohm shunt in order to damp its movements. A condenser is bridged across the output terminals of the tube to provide a low impedance path for the alternating current.

When the volume indicator is connected to a circuit in which there is a varying alternating-current potential due to voice currents, phonograph music, etc., the needle of the galvanometer will move rapidly back and forth, the magnitude of this movement depending on the alternating voltage across the circuit to which the volume indicator is connected. Due to the wide variation of this movement, it is necessary to select a given needle throw which will occur at periodic intervals in order to establish a standard deflection. When the needle moves over a range of about thirty divisions, on the average of once every 10 seconds, a satisfactory standard deflection is established. Smaller fluctuations may occur more often than this and occasionally a deflection considerably beyond thirty divisions may occur but these can be disregarded.

The power level that is thus indicated can be determined by noting the dial setting of the volume indicator. The following table gives the levels for the different dial steps when the indicator is bridged on a 500 ohm circuit.

Dial Steps	1	2	3	4	5	6	7	8	9	10	11
Power Level in Miles	+22	+20	+18	+16	+14	+12	+10	+8	+6	+4	+2

As shown on Drawing No. 906-673, there are three input terminals marked "C," "H," and "L." The "H" and "L" terminals are connected to one side of the coil through a key. These three terminals should be connected to the correspondingly marked terminals on the volume control panel. The purpose of this arrangement is to enable the range of the volume indicator to be extended so that the highest power levels put out by the amplifiers can be properly indicated. When the key is operated to the side marked "L" the reading of the volume indicator is direct. When the key is operated to the side marked "H," 20 miles should be added to the reading of the volume indicator. Then the output of the amplifier is greater than +22 miles the key should therefore be operated to the side mark-ed "H" and when +22 miles or less, the key should be operated to the side marked "L."

In addition to the use of this device as outlined above, it is also employed in the 4-A gain testing circuit which wi11 be described in a later division.

1.15 Testing Apparatus

In order to measure the gains of the amplifying system, it is necessary to emp1oy gain-testing equipment which has a gain range up to 110 miles. The amplifier to be measured is connected between suitable artificial lines and alternating current is applied to the input line which attenuates this down to an amount which will not overload the amplifier. The output voltage is then compared with the input voltage by a suitable means and the gain is obtained from the sum of all the artificial lines used. At the present time, the only available testing apparatus for this purpose is the 2-A repeater gain set equipped with auxiliary artificial lines to extend its gain range. A new gain-testing circuit, to be known as the No. 4-A gain set, is now under development and is expected to be cheaper and generally more satisfactory for this class of service than the 2-A repeater gain set. Both types of testing equipment will be described in the following divisions.

1.151 2-A Repeater Gain Set. In addition to the 2-A repeater gain set and the 50-A artificial line, several artificial lines are required in order to extend the range of this gain set so as to be able to measure the maximum gain of the amplifiers. The input artificial line has an impedance of 800 ohms and a range of 40 miles in 10-mile steps. An artificial line similar to the input line is provided in the output circuit. In addition to these two lines, a U-type line is also required to reduce the impedance of the set when connection is made to the transmitter circuit of the transmitter amplifiers. A schematic diagram of this gain-measuring circuit is shown on Drawing No. 906–852. The 2-A repeater gain set is more fully described in Bulletin No. 27 which accompanied G. E. C. *[General Engineering Circular - Ed.]* No. 1160. Any oscillator which has a satisfactory wave shape and has an output sufficient to send 10 miles into 1,000 ohms will be satisfactory for use with the above testing circuit.

1.152. 4-A Gain Set. On Drawing No. 906–851 is shown in schematic form the gain-measuring circuit employing artificial lines and a volume indicator. This consists of a series of input artificial lines as shown, three of which are the so-called H-type having a 500-ohm impedance. Two U-type lines are also provided. One U-type line reduces the impedance of the testing circuit to 200 ohms and is required when measuring the transmitter amplifiers. The second U-type line raises the impedance of the testing circuit to 4000 ohms, and is required when either of the two power amplifiers is measured alone. The potentiometer which is provided on the input has a range of 10 miles in 1-mile steps. This potentiometer is shown in detail on Drawing No. 906-674. The output potentiometer is provided with three steps, so that the proper output load condition can be obtained when measuring the different amplifiers. The zero step is used for the output of any of the amplifiers when tested

alone, the 20–mile step for the 9-A and the 30-mile step for the 10-A amplifier when tested in combination with either the 8-A or 11-A units. The volume indicator is arranged on a switch so that it may be connected either to the input or the output as required. An oscillator which will give testing currents at 200, 1000 and 3000 cycles is being developed for use with this gain-testing circuit, but its design is not sufficiently far along to be described at this time.

1.2 Equipment

In the Public Address Systems the equipment required consists of transmitters, amplifiers and projectors; each of which is designed to reproduce faithfully all sounds falling upon the transmitter diaphragm. This equipment with the necessary auxiliary apparatus is described below.

1.21 Transmitter

Special designs of transmitters and transmitter mountings have been found necessary for use with these Systems. Owing to the requirement that the transmitter shall pick up weak sounds, such as the voice from a speaker several feet away, restrictions are imposed on the mounting which require special consideration. It must hold the transmitter so that the slightest mechanical jar or vibration will not cause enough noise to be objectionable. It must be inconspicuous or of a pleasing appearance and so arranged that its location in accordance with the requirements of the acoustic systems will not be objectionable.

1.211 Transmitter Element. The No. 369-W transmitter has been designed for general use for this service. It was formerly the special transmitter per D-76577. It is of the so-called push-pull, stretched-diaphragm, air-damped type employing two carbon buttons, one on each side of the diaphragm.

The diaphragm is held by the transmitter frame and is stretched by means of two stretching rings to the required tension. A metal bridge on the front and the damping plate at the back each carry a button which is insulated from the bridge and carries its own electrical connection. The frame forms the common return connection.

The carbon is held in the buttons by means of thin felt washers which almost touch the diaphragm. Great care must be taken in handling the transmitters that these washers are not displaced and that carbon granules do not get between them and the diaphragm. The felt is very susceptible to moisture and care should be taken to keep the transmitters dry at all times. Careful handling is also required on account of the tension to which the diaphragm is stretched. It should never be touched as the diaphragm is very susceptible to injury.

The transmitter element is approximately 3-½ inches in diameter by 2 inches thick and weighs about 2 pounds. It is shown on Drawing No. 197-B-22 and on plates 3 and 4.

1.212 Transmitter Mountings. Two types of transmitter mountings have been designed to house the transmitter. One is the No. 1-A transmitter mounting per D-76534 and the other the No. 2-A transmitter (formerly transmitter box per D-76612.

The No. 1-A transmitter mounting consists of a drum-shaped cage for holding the transmitter, the whole mounted on a desk stand base. The drum has perforations on all sides which are protected by fine brass mesh. Inside the frame of the drum projecting inward are four hooks which engage coil springs to connect with four corresponding hooks on the transmitter frame. In case the coil springs are not available stiff rubber bands may be used but these will require renewal at intervals. Care should be taken in using the transmitter in this mounting that it always faces the speaker or the source of sound.

The mounting cage is 6 inches in diameter and 3-½ inches thick. The diameter of the base is 5-½ inches. The complete mounting is 9 inches high. It has a burnished brass finish designed to present a pleasing appearance. The mounting is shown on

Drawing No. 144-A-48 and on plate 5.

The No. 2-A transmitter mounting is a felt-lined wooden box divided into two compartments for holding two transmitters. The transmitters are suspended in the same manner as in the transmitter mounting. The face of the box has two openings covered with black cheese cloth and protected by metal plates when not in use. In mounting the transmitters in the box the front of the transmitters, i. e., the side which has the bridge out from the frame for supporting the button, should always be facing the front openings.

The box is 15 inches wide, 7-¼ inches high and 4-¾ inches deep. It weighs 7 pounds when empty. Drawing No. 197-B-23 and Plate 6 show the details of the box.

A No. 1-A pedestal per D-76611 is provided for mounting the transmitter box when desired. This consists of a cast–iron base 16 inches in diameter and an adjustable hollow pipe upright. This provides for a possible adjustment in height from about 4 feet to 6-½ feet. A specially designed jack is provided as part of the pedestal for making contact connection with the transmitter circuit on the box.

The weight of the pedestal and jack is 56 pounds, the pedestal alone weighing 46 pounds. The pedestal is shown on Drawing No. 144-A-49 and on Plate 8.

In a number of instances, due to local conditions, it has been found advisable to mount the transmitter box on the reading stand or other furniture on the platform. For this purpose, the No. 2-A pedestal, formerly known as the reading stand per D-76610, has been designed. This consists of a pedestal base with a reading shelf. The stand weighs 58 pounds and is adjustable in height from 3-½ feet to 6 feet. It is shown on Drawing No. 197-B-24 and on Plates 7 and 9. In general the combination of the transmitter box with the reading stand should be avoided where possible. A special shielded cord has been designed for connecting the transmitter. This is known as a cord per D-76541.

1.22 Projectors

The projectors used with Public Address Systems consist of the receiver elements, housings and horns of one design or another. The selection of the horns depends on the conditions of the particular installation as covered elsewhere in these notes.

1.221 Receiver. The receiver required for all public address equipment is the No. 196-W. A cut-away view of this receiver is shown on Plate 10 and the back view with case removed on Plate 11. It combines with the No. 3-A receiver holder (formerly receiver housing per D-76535), and the No. 8-A bracket (formerly bracket per D-76536) and may be used with any type of horn desired. The frame of the receiver is designed to engage the horn directly and, in the case of the smaller horns, this forms the support. The housing is a cup-shaped casting designed to fit over the receiver. It is flanged to engage flanges on the bracket and by means of the two the receiver may be attached to any flat surface. Drawing No. 197-B-25 shows the receiver and the housing and bracket are shown on Drawings Nos. 197-B-26 and 197-B-27 respectively. The complete receiver with housing and bracket are shown on Plate 12.

1.222 Horns. Nos. 5-A, 6-A and 7-A horns are used with this system. These are shown on Drawings Nos. 197-B-28, 144-A-50 and 144-A-51, respectively, and on Plates 13 and 14. A No. 3-A pedestal per D-76537, as shown on Drawing No. 197-B-29, has been designed to mount the smaller horns. This is illustrated on Plate 15. The data regarding the horns are as follows:

Type	Material	Weight	Length	Outer Opening	Shape
5-A	Wood	190#	10-½" 3l-½"	31-½" x 17-½"	Straight
6-A	Fibre	6-¼#	38"	22-½" Dia.	Straight-flare
7–A	Fibre	6-¼#	42"	22-½"	Curved

The No. 5-A horn consists of three telescoping sections and a cast-brass throat. The wood sections are reinforced on the outside with ash supports and present a smooth tapering surface on the inside. The horn may be used with two or three sections as desired, the length being respectively 7 feet and 10-½ feet.

1.23 Amplifiers

All of the amplifiers used in the Public Address Systems are mounted on panels 19 inches wide, drilled for mounting on standard relay-rack details. This may be of advantage in permitting the use of standard relay-rack parts at times, although in general special racks are provided as part of the regular equipment. Provision is made on all the amplifiers for measuring the neces-sary currents and potentials for insuring satisfactory operation by means of jacks. The units are as nearly self-contained as possible including protection of battery leads, as it is the intention to have all external connections conform to power standards.

Connections are made to the panels by means of binding posts on a connecting strip on the back. This permits of power cabling, shielded conductors or other types of connections as desired.

1.231 Transmitter Amplifier No. 8-A. The amplifier, formerly specified per D-76527, and now known as the No. 8-A amplifier, is a transmitter amplifier consisting of 2 No. 102-D tubes and 1 No. 105-A tube. The No. 102-D tubes, which form the first two stages of the amplifier, have their filaments connected in series. Included in this circuit are 1.3-ohm resistances for giving the proper grid potential with the normal filament current for each tube, and a rheostat and retardation coil. The No. 105-A tube has a separate filament circuit with retardation coil and rheostat, but both filament circuits are connected to the same supply leads. These will normally be 12-volt battery connections. The filament supply lead is protected by a No. 35-E fuse (3 ampere) mounted on the back of the panel.

The grid battery for the No. 105-A tube consists of No. 703 Eveready dry cells, mounted in a special type of battery box on the front of the panel. This box is equipped with terminals for checking the potential of the individual batteries. The number of 703 batteries required may be 2 or 5 depending on whether the plate potential is 130 or 350 volts respectively.

The plate-battery supply for the No. 102-D tubes is 130 volts and may be the same for the No. 105-A tube or may be 350 volts. This will normally be supplied from the battery-supply filter and potentiometer when a rectifier is used or from a motor-generator set. Since all the leads are in power wiring up to the panel no protective lamps are required. The apparatus on the panel is protected by a .1-ampere fuse in the B-battery lead. A key just below the tubes provides for variation of gain in large steps and the potentiometer between the tubes and the can cover provides for smaller steps. A special jack panel in the upper left-hand corner of the panel carries all the current-measuring jacks for the set. These include filament and plate circuits and also the battery supply for the transmitters. A battery-cutoff key is provided in the lower right-hand corner of the panel for cutting off the transmitter battery. The key for transferring the output is located on the jack mounting.

The circuit of the No. 8-A amplifier is shown on drawing No. 197-B-1 and the assembly on drawing No. 144-A-42. Plate 16 shows this panel. The space on the control-room rack required by the amplifier is 14 inches. The complete panel weighs 84 pounds.

1.232 Transmitter Amplifier No. 11-A. The No. 11-A amplifier is a single-stage transmitter amplifier employing a No. 105-A tube. The filament current required for the circuit is 1.35 amperes and may be supplied from a 12-volt battery. The lead is protected by a No. 35-E fuse (3-ampere) mounted on the back of the panel.

The grid and plate circuits for the set are similar to those for the No. 8-A amplifier

as far as battery-supply and protection are concerned. Individual "C" batteries are mounted on the panel and the same source of plate-current supply is used as for the other amplifiers.

The amplifier panel requires a space of 8-¾ inches on the bay. The weight of the panel has not been determined, as the set is not yet available. Drawing No. 197-B-5 shows the circuit and Drawing No. 197-B-6 the assembly. It will be noted that these drawings are rated "Information," as the information contained therein is not for use in specifications until the circuit is standardized. No photographs are given of the No. 11-A amplifier.

1.233 Power Amplifier No. 9-A. The No. 9-A power amplifier is furnished in accordance with Specification No. D-76529. It consists of a single-stage amplifier employing 2 No. 105-A vacuum tubes. These have their filaments connected in parallel and supplied through a rheostat and the two windings of a No. 71-B retardation coil in parallel. The total current drain in this circuit is normally 2.7 amperes. Battery may be supplied in the form of a 12-volt storage battery, the lead being protected by a No. 35-E fuse at the amplifier panel.

Grid potential is supplied from a bank of 5 No. 703 Eveready dry cells. These are mounted as in the No. 8-A amplifier with means for observing the voltage of the individual batteries. The plate potential is 350 volts, supplied and protected in the same way as in the No. 8-A amplifier.

The only adjustment necessary on this set is that of the filament current which may be made by means of the rheostat next the upper tube. Grid-battery potentials may be measured at the "C"-battery boxes. The jacks for measuring filament and plate currents are mounted under the front can cover and are accessible through an opening in this cover.

Drawing No. 197-B-2 shows the No. 9-A amplifier circuit and drawing No. 197-B-3 the assembly. The amplifier is further illustrated by means of the view shown on Plate 17. It weighs 45-½ pounds and requires 7 inches' space on the rack.

1.234 Power Amplifier No. 10-A. The 10-A or D-76562 amplifier is the high-power amplifier for public address systems. It is a single-stage 4-tube amplifier employing No. 211-A type tubes. Owing to the type of tubes involved and the nature of the circuits, special cabling is required throughout.

The filaments of the tubes are supplied from alternating current through ammeter jacks which are arranged around a special rotary plug dial and mounted in the lower left-hand corner of the panel. The ammeter is mounted on the upper left-hand corner of the panel as a part of the unit. It is an A. C. instrument and has a scale up to 4 amperes. It is arranged to read any one of the four filament currents but not the combined current. The normal filament current for each tube is 3.4 amperes and the common lead is fused for 15 amperes. All cabling in the filament circuits is with asbestos-covered, fire-proof wire heavy enough to carry the required current. It is not normally contemplated to use D. C. on the filaments and, as furnished, the set does not provide for it. If desired, however, the set may be obtained with rheostats and connections designed for D. C. filament supply. This use will be limited since an alternating-current supply will be required for use with the rectifier which furnishes the high-voltage plate potential.

The grid circuits for all tubes are supplied from a bank of 7 No. 703 Eveready dry cells. In case the filament supply is direct current, 8 cells are required. The same method of mounting these cells and of measuring their voltage is employed as on the other amplifiers.

The plate circuits of the tubes require 750 volts potential, which is supplied from the rectifier. Each plate circuit is supplied through a milliammeter jack which operates in conjunction with a rotary plug dial in the lower right-hand corner to connect the

milliammeter in circuit. In addition, a fifth jack is included for measuring the combined plate current of all the tubes. The milliammeter has two scales, one up to 100 mils and one up to 430 mils. The normal plate current is 60 mils per tube. All the wiring for the plate circuits is in rubber-covered wire which is designed to withstand potentials up to 3300 volts.

Owing to the voltages carried in this circuit, special precautions have been taken to guard against accident. A disconnect switch is provided on the back of the panel to open the 750-volt circuit when the rear cover is removed. This removes the high potential from all exposed parts on the set except the switch springs. Care should be exercised not to touch the springs, which are enclosed between the asbestos board blocks of the switch. The sleeves of the jacks are grounded and the construction of the rotary dial plug is such as to eliminate danger in the use of this equipment.

Drawing No. 197-B-4 shows the circuit of the No. 10-A amplifier and Drawing No. 144-A-43 the assembly. No guards are provided for the tubes except insofar as the handles on the two sides of the panel serve to protect them. These handles are required due to the weight of the panel and the lack of other means for handling it without injury to some of the parts. The set is also shown on Plate 18. The rack space taken up by the panel is 19-¼ inches, and its weight is 80 pounds.

1.24 Switching and Control Apparatus

Two panels have been developed for switching and controlling the equipment used in the Public Address Systems. These are the transmitter control and the volume control.

1.241 Transmitter Control. The transmitter control panel No. 515-A (formerly special panel per D-76616) is a panel designed to enable the control-room attendant to select the particular transmitter which it is desired to use or to quickly switch from one transmitter to another. Provision is made for switching any one of nine circuits to the transmitter amplifier. Normally these will consist of 8 transmitters and a gain set if this number of transmitters is used. All the switching is done by means of a dial switch so that only one position, corresponding to one transmitter, can be taken at one time. In addition to the transmitter-control switch this panel is used to mount the control-room operator's telephone set, and an artificial line. This later is in accordance with specification D-76636 and is designed to be used with the type "A" amplifier when connected to long distance lines. It will not normally be required, since the "D" amplifier is designed for this class of service, and will only be furnished when specified.

The transmitter control circuit is shown on drawing No. 197-B-7 and the panel assembly on drawing No. 197-B-8. The panel occupies 5-¼ inches on the control room rack and weighs 17 pounds.

1.242 Volume Control Panel. The No. 513-A panel per D–76515 is provided for adjusting the volume in the different projectors to the desired value as described above. It consists essentially of an autotransformer, connected across the output of the "B" or "C" amplifier, with 11 taps multipled to the contacts of dial switches as shown on drawing No. 144-A-44 so that the setting of the switch determines the relative volume in the projector connected thereto. Seven dials are provided for controlling 7 projector circuits and one additional dial for controlling the volume in the observer's projector, which should be located in the control room. A key is provided in connection with each dial for cutting off the associated projector and a master key for cutting off all projectors simultaneously.

The volume control equipment is assembled on a panel as shown on drawing No. 197-B-9. The panel occupies a space of 7 inches on the rack and weighs 11 pounds.

1.25 Volume Indicator

The No. 218-A panel per Specification D-76608 is known as the volume indicator.

It is provided as a means of indicating the output from the power amplifier and serving as a basis for determining the adjustment required on the transmitter amplifier to give the required output when switching from one transmitter to another or for different speakers. It consists of a vacuum-tube rectifier, the input of which is bridged across the output terminals of the transmitter amplifier (No. 8-A or No. 11-A) and the output connected to a sensitive D. C. meter so that the voltage across the input terminals is indicated by the degree of deflection on the meter. When switching transmitters or adjusting for different speakers the gain of the transmitter amplifier is adjusted until the deflection on the meter of the volume indicator is equal to that required for satisfactory operation as determined by previous tests. The volume-indicator circuit is arranged as shown on Drawing No. 197-B-10. It requires one No. 102-D vacuum tube, filament current for which is supplied from the source used for the transmitter amplifier. In case the equipment is located so that a tap can be obtained from a 130-volt telephone-repeater "B" battery, this may be used for supplying the plate current. Otherwise a 130-volt dry-cell battery must be provided, as the 130-volt tap from the filter potentiometer will not be suitable for the volume indicator. A jack is provided for measuring the filament current, and a battery-cutoff key for opening the filament circuit when the panel is not is use.

The volume indicator is assembled on a panel as shown on Drawing No. 197-B-11 and Plate 20. The panel requires a space of 7 inches on the rack and weighs 26 pounds.

1.26 Testing Apparatus

The testing apparatus required in addition to the control and switching equipment mentioned above and the meters mentioned later consists essentially of a gain set and oscillator for measuring the gains of the separate amplifiers or the complete system as a whole. Pending the final development of the oscillator which will be especially designed for this service, any oscillator which will give the desired frequencies may be used. A No. 4-A oscillator will be satisfactory.

1.261 No. 2-A Gain Set. Where available, a No. 2-A repeater gain set, as described in Bulletin No. 27, "No. 2-A Repeater Gain Set" may be used for measuring the gains of the different amplifiers. When using the 2-A gain set, it will be necessary, however, due to the large gains of the amplifiers, to employ a 40-mile artificial line between the input terminals of the gain set and the input of the amplifier, and another artificial line between the output terminals of the gain set and the output terminals of the amplifier. Except for the use of the artificial lines, the use of the 2-A gain set when measuring the gains of the amplifiers used in this system will be exactly the same as when measuring repeater gains as described in Bulletin No. 27.

1.262 Gain Set. A gain set designed especially for measuring the gains of amplifiers in the public address system is now under development. This set will be known as the No. 4-A Gain Set. It will consist of a potentiometer arrangement adjustable in one-mile steps supplemented by 10-mile, 20-mile and 40-mile artificial lines which may be cut in or out by means of a switch, thus permitting gain measurements to be made from -10 to 120 miles in 1-mile steps. With the special gain set, the volume indicator described above will be used as the indicating means and the method of making measurements is described in detail later.

1.27 Power Apparatus

Power equipment will be required for supplying the filament and plate current to the vacuum tubes. Where a No. 10-A amplifier is employed, a rectifier is required for supplying the plate voltage. Where a No. 10-A amplifier is not used, a motor-generator set may be used for supplying the plate current to all amplifiers. In any case, a storage battery will be required for the filament circuits of all but the No. 10-A amplifier.

1.271 Rectifier. Due to the high voltage required on the plates on the tubes in the No. 10-A amplifier, a rectifier designed to operate on 60-cycle power is employed so that a high-voltage generator will not be necessary. This set is known as the No. 6000-A rectifier. It consists of two tubes arranged as shown on drawing No. 197-B-12 together with the step-down transformer for supplying the filament circuits on the rectifier and a step-up transformer for supplying the plate circuits. The step-down transformer has a ratio of 110 or 220 volts to 12 or 14 volts and is used simply for lighting the filaments of the rectifier bulbs. A rheostat is provided in the primary circuit of the transformer for adjusting the filament current to the required value.

The step-up transformer has a ratio of 110 or 220 volts to 2,200 volts. A rheostat is provided in series with the primary windings of this transformer for adjusting the plate voltage to the required value.

The A. C. supply is controlled by a snap switch arranged so that the filament circuit is closed with the switch in its first position and both the filament and plate circuits closed with the switch in the second position in order to prevent damaging the milliammeter in case the plate circuit should be closed accidentally before the filament circuit.

The 750-volt D. C. output lead from the rectifier is wired to a binding-post terminal on the rear of the panel which is located so that it may be strapped directly to the corresponding terminal on the filter potentiometer, both terminals and the strap being protected by the panel covers. The rectifier is assembled on a panel as shown on Drawing No. 144-A-45. It requires a space of 22-¾ inches on the relay rack and weighs 203 pounds. The panel is provided with substantial handles along the sides. These are required on account of its weight and to protect the tubes and sockets from injury.

Since the potentials employed on this unit are higher than are usually encountered in telephone practice, special care has been exercised to protect all parts. The circuits are opened by the removal of the rear cover and every precaution has been taken to protect the attendants from high voltage. Due care should, of course, be exercised in operating the equipment and only authorized persons who are familiar with the circuits and the voltages employed should be allowed to use the apparatus. It would be possible to insert a tool between units so as to encounter high voltage if work is done with the line switch closed.

1.272 Filter Potentiometer. A filter consisting of a large series reactance coil and bridged condensers is required in the 750-volt D. C. lead from the rectifier, as shown on drawing No. 197-B-13. This is a part of the No. 6000-A rectifier. In connection with this filter arrangement, a potentiometer arrangement is also provided for supplying the plate voltage for the types 8-A, 9-A and 11-A amplifiers. It will be necessary to provide separate battery for the plate circuits of the gain set and oscillator. The voltage of the 750-volt lead is adjusted to the required value by means of a rheostat in the primary circuit of the step-up transformer on the rectifier panel, as noted above, while the voltage of the 130-volt and the 350-volt leads is adjusted by means of the potentiometers on the filter panel. A voltmeter is provided on the filter panel for measuring these different voltages and a milliammeter is provided for measuring the plate current of the rectifier tubes. The filter potentiometer is assembled on a panel as shown on Drawing No. 144-A-46. It requires a space of 24-½ inches on the rack and weighs 12 pounds.

A No. 12-A filter per D-76555 has been designed for the 350-volt supply from the motor-generator set. This filter circuit is arranged as shown on Drawing No. 197-B-14 and assembled on a panel as shown on Drawing No. 197-B-15 and Plate 19. It requires a space of 10-½ inches on the rack.

1.273 Motor-Generator Set. For supplying plate potentials to the various amplifier sets, with the exception of the No. 10-

A set, a motor-generator set has been developed. This consists of a direct-current generator having an output potential up to 350 volts and capable of supplying the plate current for all of the amplifiers and vacuum-tube equipment required for a given installation with the exception of the No. 10-A amplifier. This generator is directly connected to a motor which may operate on either alternating current or direct, as desired. A 110-volt D. C. motor may be specified or a 220-volt machine as desired. The alternating-current motor will operate on either 110 volt or 220 volt, depending on the connection. These motors are interchangeable and either may be used with a given generator. In selecting the motor-generator set, consideration should be given not only to the regular power supply but to an emergency supply if one is available.

1.274 Power-Switching Panel. A power-switching panel known as a No. 517-A panel has been developed for use with the public address equipment. The circuits for this panel are shown on Drawing No. 197-B-21 and it is assembled as shown on Plate 22. This panel is designed to provide the necessary means for switching the outside power connections to care for the various circuits involved. It requires a space of 24-½ inches on the rack and weighs 75 pounds.

1.275 Meter Panel. A meter panel coded as a No. 514-A panel and containing an ammeter and two milliammeters is provided for reading the necessary currents of all the equipment which does not contain such meters on the individual set. These meters have the following ranges:

Ammeter	0–4 amperes
Milliammeters	0–5 milliamperes
	0–100 milliamperes

The panel is provided with an ammeter cord equipped with a special plug and with a milliammeter cord equipped with a No. 110 plug. This eliminates the possibility of injuring the milliammeters by plugging into an ammeter jack, as no connection will be made thereby. A key is provided for reading currents on the low scale milliammeter, the high-scale instruments being normally in circuit. The meter circuits are shown on Drawing No. 197-B-18 and the panel assembly on Drawing No. 127-B-19.

1.276 A. C. Filament Supply. The 521-A panel has been developed for supplying the filament circuit of No. 10-A amplifiers. It forms a part of the rectifier set. As shown on Drawing No. 197-B-16, this consists of a transformer designed to operate from a 110- or 220-volt power supply and to step this down to a suitable voltage for heating the filaments of the No. 211-A tubes. A rheostat is provided on the high-voltage side of the transformer to regulate the filament current within close limits as desired, and taps are provided on the low side of the transformer for adapting the set to various line voltages as required. This panel will, of course, not be required when the rectifier set mentioned above is not used. In this case the filament supply will be cared for by means of a battery.

Plate 21 and assembly drawing No. 197-B-17 show this panel. It requires 10-½ inches rack space and weighs 48 pounds.

1.277 Storage Battery. The usual battery requirements for public address service consist of a 30-ampere-hour 12-volt battery for regular use and a similar spare battery, as well as adequate means of charging the spare battery. In no case should the battery be charged while in service and the battery requirements should provide sufficient reserve for all conditions including, where justified, complete independence from power failure.

The particular type of battery which will be employed will depend upon local conditions. For some classes of service this will be such as to require portable batteries, whereas other installations may be of a more permanent nature. No recommendations are made, therefore, as to the particular types of batteries to be provided.

1.28 Miscellaneous Equipment

1.281 Racks. The rack equipment usually required for this service will be the No.

100-B rack which was formerly specified per D-76661. This consists of a rack bays spaced and drilled in accordance with standard relay-rack construction with 19-½ *[sic]* inch horizontal centers. The racks are 82" high and are designed to be self-supporting when set up on a level floor.

Owing to the weight of some of the equipment involved, provision has been made for swinging the rack to a horizontal position. It will be possible to assemble the heavier units of equipment on the rack while in this position and then to swing the rack to its normal upright position to complete the installation.

Where lighter panels only are used, the No. 100-A rack per D-76531 may be used. This is of lighter construction than the other and is only 68 inches high.

It is not the intention to follow the usual cabling methods employed in the telephone plant for this equipment, since special requirements are imposed on the system by the need for shielded cable and power leads. To provide a flexible means of cabling, rings have been provided on the back of the rack to permit the running of all conductors to the panels in an orderly manner. In general, this will provide a satisfactory means of cabling even for permanent installation.

A typical rack assembly is shown on Plate 23.

1.282 Te1ephone Sets. A No. 6046-A telephone set per D-76579, which is shown on drawing No. 197-B-7, has been provided for the use of the control room attendant. This set is mounted on the transmitter-control panel and is terminated in jacks on that panel.

An additional telephone set, known as a No. 521-A Subscriber's Set, is shown on Drawings Nos. 197-B-20 and 197-B-30 and, as specified in accordance with D-76617, has been developed for the use of observers in the audience or on the speakers' stand.

1.283 Carrying Cases. Two carrying cases have been designed for carrying the vacuum tubes and transmitters required with this equipment. These are wooden cases made up somewhat along the lines of suitcases, with suitable compartments for the various apparatus involved. No. 7-A carrying case per D-76339, which is shown on Drawing No. 144-A-52, is designed for carrying four No. 212-A vacuum tubes. The dimensions are approximately 20-7/8" x 16" x 16-¼".

The No. 6-A carrying case per D-76634 is designed for carrying 5 transmitters, 18 No. 102-type tubes and 10 No. 211-type tubes. It is shown on Drawing No. 197-B-31. The dimensions are approximately 38" x 17-¾" x 9-¾".

1.29 Packing and Shipping

The shipping cases for the various loudspeaker equipment have been designed with a view to facilitating packing and shipping the apparatus from time to time. The weights of the equipment as given above apply to the different units without packing and the total shipping weights are not known accurately. These will vary somewhat depending on the method of shipment.

Where it is desired to ship the equipment from place to place, special shipping cases will be available which are designed to mount the various panels on angle irons in the same way that the panels are assembled on the rack. This will eliminate the necessity for special packing and will facilitate handling the equipment. Such a shipping case will carry any panel or combination of panels up to about 24 inches in height. The specification number for the case is not available but it is expected that the cases can be furnished on order to be shipped with the panels initially.

1.3 Acoustics

1.31 General Requirements

The acoustic problems connected with an installation of the Public Address System are essentially simple, but considerable care is required in solving them. As every case is different, it is not possible to give detailed instructions as to how to meet all conditions. Instead, this division of the

bulletin describes the results that should be obtained end the general methods which should be used in typical installations.

The principal requirement is to have the sound at all points of the audience as uniform as practicable, for there is a relatively narrow range in which the sound will be loud enough to be easily intelligible and not so loud as to seem unnatural and disagreeable.

Especial care must be taken to prevent any form of echo which would disturb the hearers or the speaker. In outdoor installations these echoes may be encountered due to reflecting surfaces at some distance from the projectors. In the case of indoor installations in moderate or small-sized halls the reflected sound will follow after the original sound more closely, so that no distinct echo will be heard, but the quality will be distorted and the sound will continue after the source has ceased to give out sound. The resulting confusion of sound is called reverberation. In larger halls both reverberation and echoes may be encountered. The methods of eliminating these are described later.

An effect similar to an echo is produced when the hearer receives the sound from two sources over air paths of materially different lengths, for then the sound from the two sources will arrive at different times. The two sources may be either two widely separated projectors or the speaker and a projector. The electrical transmission in the system is, of course, instantaneous. It has been found that the difference between the air paths from any two sound sources of about the same loudness to any one point should be kept less than 100 feet and even that much separation is undesirable. Of course, if the sound from one source is relatively loud so that the sound from the other source is nearly inaudible, no trouble will result.

For the usual installation at which there is a local speaker, the most important acoustic problem is to prevent "singing." This singing consists of a sustained tone which the system will emit if the sound from the projector gets back to the transmitter in sufficient volume. To prevent this occurring, it is necessary to direct the projectors in such a way that the sound reaching the transmitter from the projectors is small as compared with the sound reaching it directly from the speaker. In any installation with a local transmitter, it is impossible to keep the transmitter from receiving some sound from the projectors so that singing may be caused if too much gain is used in the amplifiers. The gain at which singing commences is called the singing point. At gains just below this point, while there is no singing, the quality is seriously impaired and the sounds will be prolonged. The amplifier, therefore, should always be operated at least 6 miles below the singing point and preferably 9 or more miles below.

Another point to be considered is that, where the audience can see the speaker, the sound should come from the general direction of the speaker, as otherwise an unnatural effect is produced. For this reason, wherever possible, the projectors are grouped over the speaker's head, usually about 35 feet above the platform.

The presence of interfering noise has an important effect on the System. Such noises are particularly serious if they originate near the transmitter, for then they are amplified by the System. Noises of this type may be caused by turning pages of manuscript directly in front of the transmitter or by wind blowing past the transmitter. Any noise on the speaker's platform is, of course, objectionable, such as that caused by people moving about.

Noises at a distance from the transmitter, such as the noise caused by rustling of leaves, by street traffic, and by the crowd will not be picked up appreciably by the transmitter. They will make it more difficult for the audience to hear, but this may be partially overcome by increasing the amplification. In general, it will be found that the crowd is very quiet even on the outer edges, providing the speeches can be

heard. A particularly objectionable noise has sometimes been encountered in the past during large outdoor performances due to aeroplanes flying over the crowd, and arrangements should be made to prevent such occurrences.

1.32 Characteristics of Apparatus

In order to obtain best results, it is necessary to understand the acoustic characteristics of the transmitters and projectors and information on these subjects is given in the following subdivisions.

1.321 Transmitters. In this System in general, the transmitter is placed about three to five feet in front of the speaker, giving him a large degree of freedom in his motions. So long as he speaks in the general direction of the transmitter and does not move more than a foot or so, the system will give satisfactory service. As previously stated, with the speaker 5 feet away from the transmitter, its output is approximately 70 miles below zero level. This level, however, depends entirely on how loud the speaker talks and may vary ten miles or more in either direction.

In general the speaker should not be more than 5 feet from the transmitter as then the noise picked up or introduced by the transmitter may be of sufficient volume relative to the speech to be objectionable. Usually 3 feet is the best distance. In some cases where "singing" conditions are bad, it will be necessary to put the transmitter closer than 3 feet, but if this distance is appreciably reduced, any change in position of the speaker will cause undesirable volume variations. When it is known that the principal speaker has a particularly weak voice, it will usually be necessary to place the transmitter closer, even under the best acoustic conditions. In such cases, the speaker should be advised to stay in the same place throughout his speech. The provision of a reading desk helps to keep the speaker in one place. Another method is to place a small rug at the proper location for speaking, or to paint a circle on the floor.

Music is usually louder than speaking, so that the transmitter may be placed further away and this should be done, especially for choruses, orchestras or bands; so that the various parts will be more nearly at an equal distance from the transmitter. The musicians should be especially grouped to give the proper effect whenever possible. The best arrangement for any special condition can be determined only by test, but in general it may be said that the soloist should be considerably closer to the transmitter than the rest of the musicians. Also string or bass instruments should be slightly closer than the rest, the former because they are weaker and the latter because the system is less efficient at low than at high frequencies.

1.322 Projectors. There are three types of horns available for use in the projectors, the No. 3-A, No. 6-A and No. 7-A shown on Plates 13 and 14 and Drawings Nos. 197-B-26, 144-A-50, and 144-A-51 respectively.

The No. 5-A is a 10-½ foot wooden horn made in three sections. Its cross-section is rectangular, and it is mounted with the longer dimension of the rectangle vertical. It is particularly designed to be highly directional and to project the sound to long distances. Its sound field has a horizontal angle of 30°, that is, twelve such projectors radiating from a point will cover a complete circle with practically uniform intensity. Fair results on be obtained with 45° spacing but the distribution of sound will not be so uniform. These projectors are usually mounted about 23 feet above the transmitter and the axis of the horn is directed slightly downward. Due to the various heights of mounting, the differences in slope of the ground, and other considerations, it is not possible to specify the slope of the horns exactly, but if the axis of the horn intersects the ground somewhat inside of the outer edge of the space occupied by the crowd, the distribution should be satisfactory. When possible, these projectors should be installed with adjustable slope and then the working slope

determined by test as described later. In the usual case, when there is a local speaker with the projectors mounted directly over his head, the distribution should be such that an observer walking away from the speaker' platform would receive approximately uniform intensity Of sound, first direct from the speaker and then from the projectors without noticing any appreciable transition.

In places where the range required is less than 400 feet and singing is not a controlling factor, it may be desirable to use the two smaller sections of these three-section horns, though a 6-A horn would be more suitable. Leaving off the large section makes the horn slightly 1ess directional and gives a resulting loss in distance which can be covered, but makes the projectors easier to handle.

The Nos. 6-A and 7-A horns are made of fibre and are approximately 36 inches long. They have a circular cross section, and a marked flare toward the large end. Due to this shape, and the short length, these horns are not quite so directional, giving a good volume distribution over an angle of about 45°. The Nos. 6-A and 7-A horns differ from one another only in that the axis of the latter is curved, and of the former straight, giving added flexibility in mounting in various locations. The No. 7-A horn is particularly designed for mounting close to a wall when space is an important consideration. Similar horns of metal and wood have been used before the standardization of these horns, and these may also be used when available. These flaring horns are not designed for projecting sound to great distances, but they are extremely useful for filling comparatively small spaces and projecting to distances of less than 400 feet.

1.33 Outdoor Installations

The simplest acoustic problem in connection with the system is an outdoor installation on a large, unobstructed, level field. In this case the speaker is on a stand with the wooden projectors 25 feet or so above his heed and radiating in a circle, as previously explained. The transmitter should be at least 3 feet back from a line under the mouths of the projectors. As no obstructions have been assumed, there can be no echoes in this case, but there may be slight reverberations on the stand itself, due to reflections back and forth between the floor and the ceiling. This can be reduced by laying a carpet on the floor and draping the ceiling, though in general the latter will not be necessary. The carpet not only cuts down reverberation, but deadens the noise caused by people walking about on the platform.

In any actual installation, it will generally be found that there are obstructing surfaces of some kind, such as buildings, hillsides or foliage, which will introduce echoes. In such cases it is best to point the horns down further than normally, and reduce the volume. In this way the sound will be very largely absorbed by the audience, and the echoes sufficiently reduced.

In an outdoor instal1ation the wind has an important effect on the sound distribution and on echoes, so that conditions during a performance may differ materially from those during tests. It is necessary, therefore, to have volume observers distributed around the outer edge of the crowd to report on the volume and one near the stand to report on the amount of echoes. Then the volume from each projector may be adjusted in accordance with reports obtained from these observers. If there are not enough control switches for all the projectors, two or three adjacent projectors may be grouped on one switch. In general, these projectors should be connected in parallel.

If there are to be incoming speeches from a distant point as well as a local program, it will be necessary to provide for covering the speaker's stand and the portion of the audience normally covered by the local speaker's voice. This can usually be done by providing one or more short flaring projectors pointing down from the

roof of the stand. When the local transmitter is in use, these projectors must be disconnected, or singing may result.

An approximate estimate of the energy levels required by the projectors is an essential part in laying out an installation. The following table gives approximate data which will assist in this estimate. The first column gives the distance which is to be covered by a 10-½ foot projector; the second column the energy level required under normal conditions; and the third the number of projectors working at that level which one type C amplifier will supply:

Distance	Energy Level Projector	Number of Projectors
1000	+34 miles	4
500	+19 "	100
200	+10 "	700
100	+7 "	1400

Since in general, different projectors will require different amounts of power, it will be necessary to add up the power requirements for all projectors, using the chart on Drawing No. 910-305. First the volume level of each projector is estimated from the above table. Then the corresponding power, in arbitrary units, is obtained from the chart, and the sum of these powers obtained. This sum can then be converted back to energy level by means of the chart. The resulting level must not be over 40 miles for one type C amplifier.

1.34 Indoor Installations

The acoustics of an indoor installation present entirely different problems. While in an outdoor installation a part of the sound energy is radiated off into space, and only a part is reflected or absorbed, in an indoor installation none is radiated, and a large part is reflected back and forth by the walls until it is gradually absorbed by the audience, draperies and other absorbing material. This causes serious reverberations in most halls. The reverberations in any hall may be judged by observing the effect when someone is talking loudly. Another method of value after a little experience has been obtained is to listen to whistling or clapping and noting how long it takes for the sound to become inaudible after the source of sound has stopped. In general, it will not be possible to make any such test when the hall is filled with an audience, but some idea of the reverberation under such conditions may be obtained by inquiring about the general reputation of the acoustics of the hall. Unless a hall has especially good acoustics, it is usually desirable to introduce draperies such as flags and bunting, to as great extent as possible, especially on any plane walls which the sound from the projectors strikes directly. The audience itself is the best absorbing medium, and so as much of the sound as possible should be directed toward it.

The effect of the audience in an indoor installation is so marked that preliminary tests without an audience should not be taken as a final indicator of the results that will be obtained. The audience cuts down the reverberation materially, and so makes acoustic conditions better, but it also absorbs so much sound that it is necessary to increase the amplification.

Due to the large amount of reflected sound in indoor installation, a larger proportion of sound energy necessarily gets back to the platform as compared with outdoor installations. Since the total energy is comparatively small, however, singing can usually be avoided by using no more amplification than necessary, and by placing the transmitters rather close to the speaker.

For small halls the flaring horns are more suitable, and two to five projectors should be sufficient if the platform is at one end. They should be mounted generally 25 feet above the platform. In halls with extremely low ceilings, the projectors may be mounted lower where necessary, and for halls with high ceilings and high balconies, a higher mounting should be used. The projectors should be pointed in such a way as to cover the more distant parts of the audience directly, in so far as possible.

For installations in large armories and similar halls, the problem of choosing and placing the projectors is somewhat similar to the outdoor case. Much more energy is required than in small halls, and to prevent its getting back to the transmitter the No. 5-A horns should be used when projecting 250 feet or more. For shorter distances the No. 6-A horns may be used or two sections of the No. 5-A.

The location of the speaker's stand is usually determined by fixed seating arrangements but, if any choice is allowed, it is well to locate it in the center of the hall for extremely large halls and in the center of one of the long sides for moderately large halls. When possible any location of the stand facing a large blank wall should be avoided on account of reverberations and echoes.

In such cases the projectors are usually suspended from a ring as shown in Drawings Nos. 144-A-59 and 144-A-60 and photographs on Plates 2 and 8 to 10 will be needed to cover 360°. When there are several high balconies, it is sometimes necessary to use two circles of projectors, one pointing slightly up to cover the upper balconies and the other slightly down to cover the lower balconies and the floor.

It will often be found that a low overhanging balcony will effectively shield the seats under it from the projectors. If this is the case, the projectors should be directed so as to reach as far as possible under the balcony. If satisfactory results can not be obtained in this way, it may sometimes be necessary to use small projectors mounted under the balcony. This is undesirable since the sound will not seem to come from the direction of the speaker and since in certain regions sound may be heard from the main group of projectors as well as from these auxiliary projectors. If it is necessary to use these auxiliary projectors, therefore, extensive tests must be made to make sure that the best effect is obtained.

As in the outdoor case, it will he necessary in any but the smallest halls to use short projectors pointing downward to cover the speaker's stand and the adjacent portion of the audience during incoming speeches from distant points.

Due to the extreme variations among different halls, it is difficult to specify the volume levels required. It may be said, however, that energy required for the whole group of projectors, in any except the largest hall, is roughly proportional to the cubic contents of the hall and the approximate volume level may be obtained from Drawing No. 910-306. The adjustment on each projector should be determined by tests. When there is a local speaker the speaker's voice will supply a considerable portion of the energy required so that somewhat lower energy levels will be required from the System.

As the presence of the audience has a large effect on the volume of sound, it will be necessary to have at least one observer in the furthest part of the audience to report on the volume to the control room. In the largest halls three or four observers should be used, in different parts of the audience: one under the balconies, others in any parts of the audience which are the most difficult to cover, and one near the speaker's stand to report on excessive reverberations or echoes. The grouping of projectors or the volume-control switches in an indoor installation should be different from the grouping in an outdoor installation. As there is no wind, symmetrically placed projectors which will always require equal volume, rather than adjacent projectors, should be grouped on a single switch.

1.35 Special Cases

As already stated nearly every case is different but there are certain special cases which may be considered in this bulletin sometimes the audience may be divided into two or more parts. This case will arise when there is an indoor meeting with an overflow meeting outside. Then, providing the two parts of the audience are acoustically separated, the indoor installation is no different from the usual local-speaking indoor installation and the out-

door installation is the same as a simple outdoor installation without local speaking. The projectors would be supplied from the same amplifiers. Volume observers would, of course, be required in each part of the audience.

Whenever possible, if the audience is divided into distinct parts in this way; the different parts should be separated acoustically so that the sound from the projector supplying one part will not disturb the other parts. In exceptional cases it may sometimes be necessary to install a system where the two parts of the audience can not be separated acoustically. One case of this kind encountered was an open amphitheatre with the overflow crowd outside. This condition can be met by using separate groups of projectors for the inside and outside but, in order to prevent the projectors outside from interfering with the acoustics inside, considerable experimenting must be done in placing the projectors and adjusting the volume. This type of installation, should always be avoided when possible and never undertaken unless sufficient time is available for experimenting with various arrangements.

There are occasional requests to use the System for amplifying sounds from various parts of a large stage simultaneously, as would be necessary in connection with operas, theatrical performances, or orchestral music. This would probably require several transmitters around the stage but up to the present sufficient experience has not been had with such installations to issue instructions for them. Further investigation is to be done to determine what means are most suitable for this purpose.

1.36 Phonograph Music

In most cases where the system is installed it will be desirable to supply music at some times. The usual method is to supply the music for the System by phonograph. Any good commercial type of phonograph is suitable but a particular instrument should be chosen for freedom from rattling and resonant distortion. In addition it should reproduce low frequencies well. All records should be tried out over the system in advance, as some will be found to give much better results than others.

No special attachments are required for the phonograph, as the No. 369-W transmitter connected to the amplifier system is simply placed in front of and slightly to one side of it. A special room, however, should always be provided for the phonograph. This room only needs only be about 5 feet square, but its acoustics must be carefully considered. It should, in general, be located close to the control room but must be solidly built so that it will be comparatively quiet, since any noise entering it will be picked up by the transmitter. If the sound from the monitoring projector gets back to the transmitter, there is danger of singing and distortion. If a room with bare wooden walls inside were used, the reverberations would have a serious effect on the quality, while the completely padded room would make the music sound unnaturally muffled. The best condition will usually he obtained with about three-quarters of the inner surface covered with one-inch hair felt or with thick draperies. The felt or draperies will also assist in insulating the room from outside sound.

Usually the transmitter should be two or three feet in front of the phonograph, a little to one side, though a better position to meet local conditions may possibly be found.

1.4. Long Lines Service

In this division various arrangements are described for using the public address system in connection with toll lines. These arrangements are for giving one-way service only, the arrangements for furnishing two-way service being still in a development stage.

The loud-speaker apparatus imposes more severe transmission requirements on the lines than does the handling of regular telephone service. In general, non-loaded open-wire circuits, or extra-light-loaded cable circuits, are the only ones which can be employed. The non-loaded open-wire

circuits should preferably be No. 8 gauge and equipped with the improved-type repeaters having 3,000-cycle filters. Whenever the open-wire circuit contains sections of cable, these should preferably be extra-light-loaded if more than one or two miles in length. Special precautions should be taken to avoid the introduction of any loading other than extra-light in the circuits, since such loading has a seriously adverse effect on the quality.

For the connections between the terminals of the Long Lines circuits and the loud-speaker control room, it will be satisfactory to employ non–loaded cable circuits. If these have an equivalent greater than about two miles, equalizers should be provided to keep the transmission at different frequencies substantially uniform, methods for applying these equalizers being covered in a separate set of notes.

1.41 Transmitting (One Way)

There are two types of service in which Long Lines transmitting is involved: (1) where transmitting to a distant point only is required, and (2) where local service is given, and. in addition this is transmitted to some distant point.

1.411 Transmitting Only. The requirements at the transmitting end are quite simple, involving a suitable high-quality transmitter with an amplifier to raise the volume to the correct level and means for maintaining this transmission level approximately constant.

For distant talking a 369-W transmitter should be employed in the manner discussed elsewhere in these notes. For close talking another type of transmitter which is now under development will give good results. This close-talking transmitter puts out an energy level only about 20 miles below zero.

When the 369-W is employed, an 8-A amplifier will be required. With the close-talking type of transmitter an 11-A amplifier should preferably be employed although an 8-A amplifier can be used if an 11-A is not available.

The transmission level delivered from the amplifier should be such that the level at the point where the local loops meet the long-distance circuits (the toll test board) will be approximately zero. This zero level is specified, since the repeaters associated with the toll lines are ordinarily laid out so that they will not accommodate greater volume without serious distortion. Obviously, if the level is allowed to be materially weaker, the effect of line noise will be made more serious.

The transmission level delivered by the transmitting amplifier should preferably be kept at its maximum value +10 miles, provided this will not result in too high a level at the toll test board. If the equivalent of the loop, including its equalizer, is less than 10 miles, it will be satisfactory to reduce the volume delivered by the transmitting amplifier if the loop is quiet. If the loop is noisy, a +10 mile level should be applied by the transmitting amplifier and the volume reduced at the toll test board by the insertion of a suitable distortionless artificial line or pad. If the transmission equivalent of the loop is greater than 10 miles, it will be desirable to employ a suitable one-way amplifier having a flat transmission characteristic at the long-distance test board to raise the transmission at that point.

In order to insure that the proper volumes are being delivered, it will be desirable to provide a volume indicator either at the long-distance test board or associated with the output of the transmitter amplifier. This is particularly necessary when the distant-talking type of transmitter is employed.

1.412 Transmitting with Local Service. It is frequently desired to provide local service in addition to supplying transmission to a distant point. The arrangements of the transmitter amplifier and power amplifiers for this condition are the same as for local service. The distant point, however, is provided through the output of the power amplifier, using one of the projector circuits at the volume-control panel. Since this circuit is unbalanced, it will be

necessary to provide a repeating coil between it and the circuit going to the Long Lines test board. In order to minimize interference in the cable, it is desirable to ground the middle point of this coil on the side connected to the cable circuit, or if this is not possible, a shielded coil should be used.

The power level put out on the cable circuit should ordinarily be +10 miles as explained above. When the power output from the amplifier is greater than +30 miles, the volume control circuit does not have sufficient range to reduce the level to +10 miles. In such cases an inequality-ratio transformer may be conveniently employed to step the voltage applied to the line down to the desired value. For this purpose an output transformer so connected as to have an impedance ratio of about 6000 to 600 ohms, or in other words 10 to 1 should be used. This will step the voltage down by about 10 miles, which will enable the proper level to be applied to the line. The low side of the coil should be connected to the line side with its midpoint grounded. If it is not possible to secure a coil having the proper ratio, a 1-to-1 coil may be used with 1000 ohms connected in series in the lead between the dial switch and the 1-to-1 coil. This will reduce the voltage applied to the line by about 10 miles. This latter arrangement, however, is not as desirable as the use of an inequality-ratio coil. The low side of the coil should always be connected to the cable circuit.

1.42 Receiving

There are two types of service in which Long Lines receiving is involved: (1) where receiving from a distant point only is required, and (2) where local service is given and in addition transmission is received from a distant point and projected in the same installation as the local service.

1.421 Receiving Only. When receiving transmission from the Long Lines, it may be necessary to use a one-way repeater at the test board. Whether this is required or not will depend on the power level of the transmission received from the Long Lines at the control room. If the power level at the control room is lower than -15 miles, a one-way amplifier at the test board should be provided. It may be necessary, even though the power level is not as low as this, to provide a repeater at the test board, if conditions are such that considerable noise and interference is to be encountered in the loop between the test board and control room. For such a condition it will be desirable to send the transmission out at the test board to the loop at a plus 10 mile level.

The receiving amplifiers at the control room should consist of a No. 11-A amplifier, which is connected directly to the loop, and a No. 9-A or No. 10-A power amplifier as required. If a No. 11-A amplifier is not available, a No. 8-A amplifier may be used in its place, but due to its large gains will require an artificial line in front of it to reduce its gain. This artificial line is mounted in the transmitter-control panel when specified and is cut in circuit by operation of a key. The line has a 20-mile loss, and has an impedance of 500 ohms on the side which is connected to the loops. The latter arrangement mentioned is not as satisfactory, since the transmission frequency characteristic of the No. 8-A amplifier is not quite as good as that of the No. 11-A amplifier.

1.422 Receiving with Local Service. It is frequently desirable to do both receiving from a distant point, and also carry on a local program. For this condition there are two cases, the first where distant talking is involved at the local installation, and the second where close talking only is required. For the distant-talking condition, a No. 8-A amplifier should be provided for the local transmission, which will be connected to the power amplifiers as required. For receiving the transmission from the Long Lines circuits, a No. 11-A amplifier should be used ahead of the power amplifier. The change from local to Long Lines conditions can be readily made by operating the switches on the amplifier units themselves.

Where the local performance requires the use of a close-talking transmitter only, the No. 8-A amplifier can be omitted and the local installation will consist simply of a No. 11-A amplifier and a power amplifier. The change from local to Long Lines condition can then be made by the operation of the input switch in the No. 11-A amplifier.

2. OPERATION AND TESTING

2.1 Field Survey

Before any actual installation of the Public Address System is attempted, it is essential that a field survey be made of existing conditions. Such a survey is required to determine primarily whether it is possible to furnish the desired service, and if so, to give sufficient information for the selection of suitable apparatus and determination of the manner in which it should be installed. The more complete this survey, and the better the judgment displayed in choosing proper equipment and location, the less the difficulties that will be experienced in installing and operating satisfactorily.

It is essential, therefore, that a man of experience and judgment be placed in charge of this field survey. He should, furthermore, be thoroughly familiar with the Public Address System and its possibilities, as described in this bulletin.

2.11 Acoustic Conditions

Two main features are to be considered in connection with the acoustic conditions of the place where an installation is proposed.

2.111 Noise. Interfering noise is to be avoided, as it obscures the speech and makes necessary larger power to overcome it and give satisfactory results. If there is any freedom of choice, a location should be selected as much as possible removed from street traffic, railroad yards, or other possible sources of interference. In the case of amusement parks, state fairs, and the like, there will often be sources of interfering noise which are not in operation during the preliminary survey but which may be during the period when it desired to operate the Public Address Sy tem. If, therefore, such sources of poss ble disturbance are not taken into accou before hand, the results may be unsatisfa tory. It is in all these cases advisable choose equipment which it is entirely cer ain will furnish an ample margin of power overcome any possible noise interference.

One of the factors to be given special a tention is the location of the speaker transmitter where it will be as muc shielded from undesirable noise as poss ble. If it is not so shielded, the noise w of course be picked up by the transmitt and amplified through the entire system.

2.112 Topography and Building Co ditions. In considering possible locatio for an outdoor installation, it should b borne in mind that any obstructions su as uneven ground, intervening building or dense foliage, cast distinct sound sha ows and may cause echo and reverber tion. To get even distribution of spee and good quality, it is desirable to sele flat open ground without obstructions, a suf-ficient1y large to accommodate the e pected audience without crowding.

In the case of indoor installations, acou ic conditions will, in general, be more di ficult to meet; chiefly due to echo and r verberation. As noted in Section 1. Acoustics, it will often be necessary these cases to cover flat unbroken wal with bunting or other sound absorbi material to avoid this trouble. The nece sity for such treatment and the possibiliti of carrying it out should be carefully co sidered in this field survey. Final det mination of such necessary correcti measures can of course be made only aft the equipment has been installed and a ual tests have been made. As much gen al information as possible on the acous properties of auditoriums should be o tained before the installation is made.

Overhanging balconies are likely many auditoriums to be a further source trouble. In the case of more or less temp

rary structures, such as convention halls, it may be possible to modify or change the actual construction plans to avoid excessive overhang. In permanent structures, this is of course impossible, and the presence of balconies of this sort should be carefully noted in the preliminary survey.

2.12 Power Situation

Complete information should always be obtained beforehand as to possible sources of power supply. In particular, the voltage available, the frequency, and the general dependability of the source of supply should be noted, as well as the carrying capacity of the supply circuits available. It is of course desirable to choose a location for the installation which will not require excessive construction work. The amount of construction necessary to furnish power to the selected location should be noted, and definite information obtained of the time required to do it.

In some cases where it is highly important that there be no interruption to service and the source of supply seems not altogether dependable; it may be desirable to install an auxiliary emergency power plant driven by a gas engine. In general, such measures will not be required.

2.13 Telephone Facilities

It is always necessary to furnish local telephone communication to the control room. Available facilities should be determined, paying particular attention to any necessary construction work.

If long line connections are desired, the types of line available should be carefully considered in connection with Section 1.4, Long Lines Connections. The best available routes to the test board should be selected. The question of drawing-in additional circuits and of improving the transmission characteristics of existing circuits, should be thoroughly reviewed.

2.14 Selection of Location

A final determination of the best location for the equipment can be made only after consideration of the points noted above. The relative importance of these various factors depends very largely on local conditions.

2.141 Speaker's Stand and Projectors. The proper location and construction of the speaker's stand and support for the projectors is a large element in the success of any installation of the Public Address System. These points should be particularly borne in mind in finally determining this location.

1. Avoidance of obstructions, echoes, and interfering noises.
2. Avoidance of unnecessary construction expense in the way of horn support, power supply, or telephone service.

In many cases it will be found that questions of appearance and individual preference on the part of those for whom the installation is to be made, will materially affect the choice of a location. Every effort should, of course be made to prevent individual preferences from introducing complications in installation or operation.

2.142 Control Room. The control room should be placed, in all cases, near the speaker's stand so that the wiring from the transmitters may be as short as possible. Where the stand is outdoors, provision should be made, if practicable, for a control room under the platform. In other cases it may be well to use a portable garage set up nearby. Space in a nearby existing building may in many cases be utilized.

Wherever it may be, the space should be large enough to provide for the equipment and operating forces without crowding. A room ten feet square should in general be large enough for the ordinary local installation. In the case of very large and important installations, or those involving long line connections and consequent additional personnel, more space than this will be required.

In addition to the control room proper, space should be provided nearby for a phonograph room and transmitter which can be completely isolated. This room, provided it is properly soundproofed, and deadened

by means of hanging or padding, as discussed elsewhere in this bulletin, need not be over five feet square.

2.143 Observers' Stations. The number of observers' stations required will depend both on the size and the nature of the installation. At least one observer is necessary in every case. Large installations may require as many as ten observers.

There acoustic conditions are expected to be fairly uniform, fewer observers will be required. Their stations should be located where acoustic conditions are expected to be worse, generally on the outskirts of the audience.

Where acoustic conditions will not be uniform over all the area occupied by the audience, more observers proportionately will be required. In oases of this kind, their stations will have to be located, not only at spots where echo, reverberation or low volume is expected, but also at least one observer will have to be stationed where acoustic conditions are average.

It is important to choose the location of the observers' stations so that immediate information may be received in the control room of undesirable acoustic conditions; both during the preliminary tests and the actual performance.

The wiring of the observers' stations may be temporary in character, but should of course be installed as inconspicuously as possible, and where it will not be liable to damage. In some cases it may be found desirable to bury the wiring in a shallow trench dug for that purpose. In other cases it may be strung on trees or other convenient supports.

2.2 Installation

After the field survey has been made and the general arrangements for the installation decided upon, the detailed requirements for the installation will be considered. These will involve the installation of the transmitters, projectors, and control room equipment, together with any telephone facilities which may be required.

Most of the cabling required in the installation should be shielded as noted. Wherever shielded cable is required No. 14 Ga. Twin Conductor BX Armored Cable, No. 18 Ga. Flexible Twin Conductor Armored Lamp Cord or Habirshaw No. 14 Twin Flat Lead-Covered Wire should be used. Any of these may be obtained from the Western Electric Company. There use will be determined by the mechanical protection necessary and the size of conductors.

2.21 Transmitters

The field survey and the general plans for the installation will, of course, determine the location of transmitters. These will be installed as required with suitable mountings to meet the local requirements. In case the transmitters are installed in the transmitter mountings and are located on a pedestal, certain flexibility will be permitted as determined by preliminary tests. In case a transmitter box is located on the reading stand very little flexibility is permissible.

A special shielded cord has been developed for use with the transmitter. This is special cord per D-76541 and the connections should be as follows:

Red tracer to front button connection.

Green tracer to back button connection.

Yellow tracer together with the shield conductor which terminates in the stay cord to the frame connection.

The cabling from the transmitters to the control room should be shielded, armored cable or armored lamp cord usually being employed. This may or may not be concealed, depending on the local conditions.

2.22 Projectors

The location of the projectors will be as determined by the field survey to meet acoustic conditions. Slight changes may be required after the installation is complete and the system is tested as a whole. The installation may involve several types of projectors and these may be mounted on side walls or parts of buildings, or grouped on a platform or set of rings. A number of installations have involved the use of two concentric rings made from iron pipe, the two being adjustable with respect to eleva-

tion so as to permit of raising or lowering the entire unit and of tipping the horns. This type of mounting is illustrated in photographs of typical installations. The inner ring should be not less than 3 in. diameter and the outer ring not less than 17 feet. It is desirable that the outer ring should meet the horns at the beginning of the last section. These rings are not ordinarily furnished and may be made up locally.

For outdoor installations, it will frequently be found convenient to incorporate the projectors in a super–structure above the speaker's stand. The details for this will be worked out to meet the particular installations involved. In several instances a steel tower has been used, as illustrated in the photographs and drawings of tvpical layouts. The details for this tower are shown on Drawing No. 144-A-64. It is intended that the tower be built locally since all the details are from standard steel sections. In case it is intended to move the tower all parts should be bolted together.

A very substantial and appropriate combined stand and tower has been built at fair grounds by setting four poles and building the platform and horn support between them.

The appearance of the projectors should be considered with reference to the type of installations involved and in general they should be inconspicuous and fit in with the general plan of architecture or decoration. Usually it will be desirable to conceal the cabling which will not require shielding and will be grouped to the various projectors as conditions may require.

2.23 Control Room

The location of the control room will usually be decided upon when the field survey is made. This will have to be decided by a consideration of the facilities available and the convenience of the control-room attendants during operation. It may necessitate extensive cabling to the transmitters and projectors. The only other cabling from the control room will be for power circuits and for telephone facilities such as order circuits and connections to long lines.

2.231 Panel Equipment. The particular panel equipment which will be required will depend largely upon the type of installation. No fixed standards for the location of the panels on the rack will be established., except that the No. 10-A amplifier will be located just above the filter and potentiometer which in turn will be mounted over the rectifier. This relative arrangement is necessary owing to the construction of the panels and to the potentials which are involved. The rest of the panel equipment may be grouped as desired for convenience in operation. Typical layouts are shown on Drawing Nos. 144-A-57 and 144-A-58. As noted in the description of the equipment, all of the control room panels are assembled with connecting strips at the back which do not require soldered connections and which are designed to take any size of wire required. The racks are provided with rings which permit bringing the cable up to the equipment in an orderly way without causing undue congestion and yet permitting a certain amount of flexibility.

All of the input and output circuits for the various panels involved and. all cabling between panels should, in general, be in shielded paired conductors. In all cases the shield should be connected to ground. All power leads coming to the control room equipment must be run in conductors up to the panels which will satisfy underwriters' requirements. In every case adequate protection is provided at the panels.

2.232 Other Control Room Equipment. The additional equipment in the control room besides the panel apparatus will consist of batteries as required for the individual installation, a monitoring projector consisting of a receiver with a No. 6-A or No. 7-A horn, a motor–generator set when this is required, and any facilities which may be required for Long Lines connections.

The location of the batteries will depend upon the type of batteries used and the permanence of the installation. For permanent installations they may then be locat-

ed in a separate battery room. Charging equipment may be provided for the batteries or these may be portable and be taken outside for charging.

The location of the rack equipment will, in general, be such as to permit the necessary number of attendants to work around the panels without interfering with other activities in the room. The power equipment such as motor–generator sets, batteries, etc., should be so located that an attendant caring for this equipment will not interfere in any way with work on the control apparatus. It is desirable where possible to locate the motor-generator set or any rotating machinery outside the control room. When this can not be done it should be located so that the noise of operation will cause the least possible disturbance to the control forces.

2.24 Order Circuits

The order circuit for use by observers in the audience will consist of a pair extending to all points which are intended to be used as observer's stations. No particular precautions other than those ordinarily taken in installation work such as concealing of wires, etc., need be taken, as this circuit does not connect in any way with the loud speaker circuits. An order circuit between the control room and the speaker's platform or other location where the progress of the program may be observed, will usually be necessary.

One or more order circuits may be required for facilitating the long lines part of a performance. It will be necessary to provide facilities for communication between the long lines plant and an attendant who has charge of the public address system.

2.3 Testing

2.31 Amplifier System

After the installation of the Public Address System has been completed a number of tests are required on the various units and the system as a whole to make sure the apparatus is in good condition and functions properly. In this connection it is first necessary to check up the amplifying system before any overall tests on the system are made. The following section describes the tests required on the amplifiers when they are first installed as well as routine tests required each time the amplifiers are used.

2.311 Use of Testing Equipment. The principal points in the operation of the two types of gain-measuring devices will be described here. The reference to the operation of particular switches will be omitted since, in general, the switching arrangements will vary with each type of installation.

The 2-A gain set may be used for measuring gains by connecting the amplifier to the in and out terminals of the artificial lines, as shown on Drawing No. 906-852, cutting in the proper amount of artificial line and operating the gain set in the manner described in Bulletin No. 27 for measuring repeater gains. A "U"-type line is provided for use when the No. 8-A amplifier is being measured, either alone or in combination with other amplifiers. Also, this line should be used with the No. 11-A amplifier when measurement is made through the transmitter battery-feed coil. This line introduces a loss of 12.5 miles and there is also a reflection loss of 0.5 mile at the output so that 13 miles should be added to the sum of the artificial lines and the dial readings. When the "U"-type line is not used, one mile should be added to the sum of the dial readings and artificial lines due to reflection losses at both input and. output. No provision is made for measuring the Nos. 9-A or 10-A units alone. The following table gives the combination of artificial lines to be used for different amplifier combinations.

Amplifiers	Input Artificial Lines	Output Artificial Lines
8-A	U + (0 to 40 as required)	0
11-A (x)	U + 0	0
11-A (y)	0	0
8-A + 9-A	U+ (0 to 40 as required)	30
8-A+ 10-A.	U + (0 to 40 as required)	40
11-A+ 9-A (x)	U + 0	30
11-A+ 10-A (x)	U + 0	40
11-A+ 9-A (y)	0	30
11-A+ 10-A (y)	0	40

(x) Measuring through trans. battery-feed coil.
(y) Battery-feed coil cut out.

To measure the gain of an amplifier using the measuring circuit as shown on Drawing No. 906-851, the amplifier is first connected to the input and output terminals of the gain circuit. Artificial lines equal in value to approximately the gain expected from the amplifier are cut in. The switch associated with the input potentiometer is operated to the side marked "gain." The input potentiometer is set on step 0 and the volume indicator is connected to the input potentiometer by means of the test key. Then, using the volume indicator for gain tests, the dial switch of the volume indicator should always be set on the step 11. The oscillator is next turned on and its output adjusted until a deflection of between 30 and 40 divisions is obtained on the galvanometer. This will represent an input current which is not too great to overload the amplifier but which is sufficiently large to override the normal amount of interference which it may encounter.

The test key is then operated to connect volume indicator across the output potentiometer. If the needle of the galvanometer falls below the point at which it was set when connected to the input, artificial lines in the input circuit should be cut out until the needle rises to or above the original setting. When this condition is obtained, adjust the input potentiometer until the needle falls to the original setting. The gain is then equal to the sum of the artificial lines used, plus the readings of the input and output potentiometers.

If, when the volume indicator is first connected across the output, the needle of the galvanometer does not drop below the original setting, adjust the input potentiometer until, it does fall to the required point. If, however, the proper setting can not be obtained by adjusting the input potentiometer, additional artificial lines should be cut in until it is possible to obtain the desired setting.

Losses up to 10 miles can be measured by cutting out all artificial lines and throwing the input switch to the side marked "Loss." The balance between the input and output voltages is then obtained by adjusting the input potentiometer in the same manner as described above for gain measurements. The loss is then equal to the potentiometer reading.

The following table gives the combination of artificial lines to be used when measuring the different amplifiers.

Amplifiers	10 Mile U Line	High Impedance U-Line	Output Potentiometer
8-A	In	Out	0
11-A (x)	In	Out	0
11-A (y)	Out	Out	0
9-A*	Out	In	0
10-A*	Out	In	0
8-A + 9-A	In	Out	20
8-A + 10-A	In	Out	30
11-A + 9-A	As required	Out	20
11-A + 10-A	As required	Out	30

(x) Measuring through trans. battery-feed coil
(y) Battery-feed coil cut out
* It will not be necessary to measure either the Nos. 9-A or 10-A amplifiers alone except when it is thought that these units are in trouble. As mentioned above, the high impedance U-line is provided for this purpose.

2.312 Current and Potential Limits. The following table gives the normal currents and potentials together with limits for the various types of amplifiers.

Type of Tubes	Filament Current Amperes Max.	Norm.	Min.	Plate Potential Volts Max.	Norm.	Min.	Normal Space Current Mils	"C" Battery Voltage Norm.	Min.
102-D	1.0	0.97	0.94		130*		0.75		
105-A	1.4	1.35	1.3	135	130	125	7.0	9.0	8.0
105-A	1.4	1.35	1.3	360	350	340	30	22.5	21.5
113-A	3.5	3.4	3.3	780	750	720	75	31.5	30

* No limits given since this is not measured.

2.313 Gain and Gain-Frequency Characteristics. The 1,000-cycle gain calibrations of various amplifier combinations are given in Table I.

Table I - 1000-Cycle Gain Calibration

No. 8-A Amplifier

Pot. Step	1	2	3	4	5	6	7	8	9	10	11	12
Low	22	25	28	31	34	37	40	43	46	49	52	55
High	52	55	58	61	64	67	70	73	76	79	82	85

No. 8-A + 9-A: Increase above gains 15 miles
No. 8-A + No. 10-A: Increase above gains 25 miles

No. 11-A Amplifier

Pot. Step	1	2	3	4	5	6	7	8	9
Low	-1	1	3	5	7	9	11	13	15
High	14	16	18	20	22	24	26	28	30

No. 11-A + 9-A: Increase above gains 15 miles
No. 11-A + 10-A: Increase above gains 25 miles

Measurements at several frequencies are also required at times to determine whether the amplifiers are functioning properly over the frequency range desired. Measurements at 200, 1000 and 3000 cycles will be satisfactory for this purpose. The following table gives the gain limits for this condition referred to 0 gain at 1000 cycles.

Table II

Gain-Frequency Characteristics - Amplifier Units

Freq.	8-A	11-A	6-A + 9-A	8-A + 10-A	11-A + 9-A	11-A + I0-A
200	-1 ±1	-1 ±1	-1 ±2	-1 ±2	-1 ±2	-1 ±2
1000	0	0	0	0	0	0
3000	-2 ±2	-1 ±1	-2 ±2	-2 ±2	-1 ±2	-1 ±2

The gain obtained on the amplifiers may differ two or three miles from the 1,000-cycle gain given in the tables mentioned above, due to differences in tubes. The shape of the gain-frequency characteristic, however, should come within the limits specified on Table II.

If, for any reason, it is necessary to measure either the No. 9-A or 10-A units alone, the 4000-ohm "U"-line shown on Drawing No. 906-851 should be connected to the input of the amplifier. On the 9-A amplifier a loss of about two miles should be obtained for this condition. For the 10-A amplifier a gain of about 6 miles should result. The gain-frequency characteristic for either amplifier should be substantially flat or slightly rising with increasing frequency.

2.314 Initial Tests. When the amplifiers are first set up the polarities of the various batteries should be first checked to insure that the proper potentials are connected to the amplifiers. After this is done the currents and potentials should be adjusted to their normal values as indicated in the table given under 2.312.

The gain of the complete system consisting of the transmitter amplifier and power amplifier should be measured at 1,000 cycles with the sets arranged to give maximum gain. If the gain indicated is satisfactory, the input of the transmitter amplifier should be short-circuited and the output from a projector should be listened to in order to determine whether the amplifiers are quiet. If, standing 50 feet away from one of the projectors, no noise is heard, the amplifiers can be considered satisfactory from a noise standpoint.

The above tests will establish if the amplifiers are in fair shape. In order to fully check them up, however, more complete gain measurements should be taken. The combination of amplifiers to be measured will depend on the particular installation involved. Where no Long Lines are involved, the transmitter amplifier and power amplifier may be measured as a single unit. If Long Lines are involved so that the transmitter amplifier is used separately, i. e., connected to Long Lines transmitting circuit or the receiving amplifiers are connected to Long Lines receiving circuit, it will be necessary to check up these units separately. For the conditions above the following measurements should be made.

1. Gain measurements at 1,000 cycles on all steps of potentiometers for the particular amplifier or particular combination of amplifiers involved. These gains should agree fairly closely with the gains given on Table I above.

2. Gain-frequency characteristics of the particular amplifier or particular combination of amplifiers arranged for their maximum gain and some intermediate step. The following frequencies will be sufficient for this: 200, 1000 and 3000 cycles. The shape of the curves thus obtained should come within the limits given in Table II above.

Check tests using a frequency about 3000 cycles with the various amplifiers set for maximum gain should be made, making a transposition in front of amplifier ahead of the input artificial line. The transposition should not affect the measured gain more than about 2 miles. If the effect is larger, it indicates either trouble with the amplifiers or with the measuring outfit.

The following tests can be made to localize the trouble. Restore the leads to the original condition and make a transposi-

tion at the input terminals of the amplifier. If the results thus obtained are different from those when the leads were transposed ahead of the input line, it indicates that the input lines are picking up interference. If the results are the same, however, restore these leads to the original condition and make a transposition at the output of the amplifier. If the results thus obtained are different from those when the transposition was made ahead of the amplifier, it indicates trouble in the amplifier unit. If the results are the same it indicates trouble due to waveshape of the oscillator.

The above tests should establish whether or not the amplifiers are in good shape. After it has been found that the amplifiers are satisfactory it is necessary to insure that the bulbs are in good condition. To do this, measure the gain of a particular amplifier or combination of amplifiers with the filament current for a particular stage set for maximum and with the filament current in the other stages normal. Next make the current a minimum in the stage which used maximum current before leaving the other stages normal as before, and again measure the gain. The difference in gain should not exceed one mile. If it does exceed one mile, it is desirable to substitute other tubes. If, however, other tubes are not available, it will be necessary to hold the filament current very closely to the maximum value specified above in order to avoid distortion or variation in gain of the system.

In addition to the above tests, measurements should be made on the autotransformer to insure that it is in good condition. The output of the gain set should be connected to the terminals of one of the projector leads instead of directly to the output of the amplifier, with the dial switch associated with this circuit set at step zero. All other projector dials should be cut off during this measurement. The input of the gain set should be connected to the amplifier input and the gain of the amplifier can be adjusted to any convenient value. Measurements should be made at 200, 1000, and 3000 cycles. The gain thus obtained should be practically the same as was obtained when measurement was made directly at the output of the amplifier. If a lower gain results it indicates that there are short-circuited turns in the auto transformer.

It will also be desirable to make a further test which will insure that the coil is not open. The gain set should be left connected on as for the above test, and a 1000-cycle tone should be applied to the input of the amplifier. A projector should then be connected and the dial associated with this projector slowly turned from step zero to step 20. A continuous decrease in the volume of the tone heard should result. If, however, very little change in the tone is noted and the tone is suddenly cut off after passing a particular step, it indicates that either the dial connection is open or that the winding of the coil is open. Which trouble exists can readily be determined by checking up dial connections. The above tests can be made for all projector dials if desired to insure that no open circuits exist in these.

2.315 Routine Tests. Each time the amplifiers are set up for use, either in a test or demonstration, the following tests should be made.

1. The filament currents, plate voltages and grid potentials should be checked up to insure that they are within the prescribed limits. (If a No. 10-A amplifier is used, it is necessary to turn the filament current on this amplifier for about 5 minutes before applying the plate voltage and making the final adjustments in order to allow the various temperatures to become constant.).

2. Check up the gain of the complete amplifying system using a frequency of 1000 cycles at some convenient setting of the potentiometers.

3. Check up the stability of the tubes in each stage as explained above.

4. With the complete system at top gain, short the input of the transmitter amplifier

and listen for noise at the output of a projector in order to be sure that the system is quiet.

2.32 Volume Indicator

2.321 Initial Adjustments. The adjustments required on the volume indicator to make this device ready for service are very simple. It is only necessary to turn on the filament current, adjust it to 0.97 amperes and adjust the grid potential until a deflection of 5 small divisions is obtained on the galvanometer. The dial switch should be set to position marked "0" when making this adjustment. The proper operation of this device requires a source of 130 volts which does not fluctuate. For this purpose the same battery which is supplied for the oscillator or gain set can be used.

The volume indicator should be calibrated frequently to insure that it is functioning properly. It is, however, only necessary to calibrate once for any given installation unless this installation is maintained for several weeks, in which case the volume indicator should be calibrated about every two weeks or whenever the tube is changed.

This calibration maybe made either by single-frequency measurements or by voice tests.

If a single-frequency test is used, connect the volume indicator across the input potentiometer of the 4-A gain set if this is available, making sure that no artificial lines are connected to the potentiometer. If the 4-A gain set is not available, connect the volume indicator across 500 ohms. A milliammeter should be connected in series with the 500 ohms or the input potentiometer of the 4-A gain set and the oscillator. Using a frequency of 1000 cycles, adjust the current through this resistance until 11.0 milliamperes are flowing. With the dial switch on the volume indicator set on step 6, a deflection of 17±1 divisions should be obtained. In general, it will not be necessary to check each step of the input coil. If, however, it is desired to do this, the same method should be followed as outlined above, keeping the current constant at 11.0 milliamperes. The following table will give the readings which should be obtained for the different dial settings.

Dial Step	11	10	9	8	7	6	5	4	3	2	1
Deflection in Divisions	60±2	48±2	37±2	29+1-½	22±1-½	17±1	13-½±1	10-½±1	9±.5	7.5±.5	6.5±5

To calibrate by voice test, connect the volume indicator across the output of either the Nos. 8-A or 11-A amplifiers with its output terminated in 500 ohms. 130 volts from a battery or a quiet generator should be applied to the amplifier using a 9-volt "C" battery on the 105-A tube. A transmitter should be connected to the amplifier and a person should talk in an even tone of voice. The gain of the amplifier should be increased until the space current of the 105-A tube is dropping about ½ to 1 mil on the average of about once every 10 seconds. Under this condition the amplifier will be putting out about a +10 mile power level. The dial switch of the volume indicator should be set on step 6. Under this condition the standard deflection as mentioned under division 1.14 should be obtained.

If the calibration is not satisfactory, it will in general only be necessary to change the tube to bring the calibration within the proper limits.

2.33 Transmitters and Projectors

When the amplifiers are found to be working satisfactorily, it is necessary to test the transmitters and projectors. Except for the measurements of transmitter currents, all these tests are largely a matter of judgment but a little experience will be required to develop the necessary judgment.

First, all the transmitters available should be connected to the circuit in turn and the currents in each button measured. The normal operating current is 25 mils per button with limits of 20 and 30 mils. If the transmitters are noisy it may be desirable to go as low as 10 mills per button. The current in the two buttons of the trans-

mitter should not differ by more than 20% of the higher current.

If a larger difference is found, the connections to the transmitter should be inspected, as incorrect connection of the three transmitter leads would cause a serious unbalance and result in poor quality and low efficiency. If the connections are right and the currents are unbalanced it indicated that the transmitter has become defective and it should not be used.

The next test is to listen to the quality and volume of the transmitters. For this purpose, two transmitters should be connected to the system alternately, while a speaker talks in the normal way in front of them and an observer listens to the sound as heard from one of the projectors. The observer should notice and record the differences in volume, quality and extraneous noise. Then all other transmitters which are available should be tested in turn against the better of the first two tested. In choosing which transmitters to use, it should be remembered that volume is not controlling since in most cases there is plenty amplification available. When two transmitters are to be mounted together, however, it is preferable to have them of about equal volume efficiency since, then, no adjustment of amplification will be required if it is necessary to change from one to the other during a performance. Sometimes a considerable difference in quality will be found among transmitters which have been used for some time, for the tightly stretched diaphragm may slip. In all cases, the transmitters giving the most natural reproduction of sound should be chosen, except when it is found that such a transmitter will give too much transmitter noise.

In making these tests on transmitters, they may be tested in any convenient location where there is little reverberation, but usually the speaker's stand where they are to be used will be found best. Only one projector should be used during these tests so that echoes and singing will not interfere with the judging of the differences in transmitter quality. It will usually be convenient to combine the measurements of the transmitter currents with these quality tests.

The transmitter currents should be checked every time that the system is operated, and if possible, occasionally during each performance. This test must not be made while the projectors are connected, however, as the insertion of the plug would cause a loud noise.

Only simple tests are necessary on the projectors. The defect that is sometimes found is a rattling sound when the receiver is used at high energy levels. Each receiver, therefore, should be operated alone at the maximum energy level which is expected to be used, while an observer listens for any indication of rattling. Any receiver that rattles should be replaced and no attempt made to adjust it. Receivers should never be tested without a horn, as taking away the horn practically removes the acoustic load on the diaphragm and allows it to vibrate too freely.

2.34 Complete Systems

After the best transmitters have been chosen and defective receivers replaced, it is possible to start tests on the whole system. In general, these tests will take some time and a large number of adjustments and rearrangements of apparatus may have to be made. The tests include the determination whether the distribution of sound, the quality of reproduction and the singing point are satisfactory.

With all the apparatus instilled and tested, as described in previous sections of this bulletin, a speaker should stand at the proper place on the speaker's platform and speak as he would before an audience. Reading should be avoided as a book or paper interferes to some extent with the sound reaching the transmitter. As he is speaking with the system operating, an observer should walk around the space to be occupied by the audience and observe whether the volume distribution is satisfactory and whether there are objectionable echoes or reverberations. In connec-

tion with the volume distribution, it is particularly necessary to make sure that the transition between the area covered directly by the speaker's voice and the area covered by the projectors is satisfactory. The observer should have a telephone connection with the control room so that he can have the volume from the different projectors regulated as required. It may be necessary to change the direction of the projectors to get the desired distribution and to avoid echoes. This work should be done with the greatest care as the whole effect of the system may be entirely changed by minor changes in the projector layout or of the volume adjustment.

In this rearrangement of projectors and adjustments the effect on "singing" must be considered. When all the adjustments have been made, the gain of the amplifiers should be increased until singing commences. This singing point should be recorded and if it is not far enough above the gain required for operation, further readjustments must be tried.

If the proper singing margin is obtained and if all the previous tests have been performed satisfactorily, the system should give good reproduction of sounds. If the quality is not good enough, it may sometimes be due to overloading of the amplifiers and this should be checked by reading the volume indicator and making space-current measurements on the system while in operation. If the space currents vary more than allowable, as specified in another division of these notes, the amplifier is being overloaded and steps must be taken to prevent this condition.

Another defect which sometimes causes poor quality is reverberation on the speaker's platform which can usually be remedied by further draping or by the use of heavy carpets.

If there is a "ringing" quality to the sound the System will usually be found to be too near the singing point.

If there is too much extraneous noise from the projectors, it may be due to a faulty transmitter, noisy vacuum tubes or noisy batteries. If the noise can not be reduced to an unobjectionable amount by replacing these pieces of apparatus, it may sometimes be reduced by pointing the projectors differently. This is because these noises are generally of a different frequency from speech or music and are therefore transmitted differently. In general, noises will only be found objectionable within about 60 feet of a projector, directly along its axis.

A cause of poor quality which is sometimes overlooked is the mounting of the transmitters improperly. They must be mounted with the front, which is the side with a bridge across it, facing the opening of the transmitter box and the speaker.

When testing an indoor installation it must be remembered that the audience will cut down the reverberation, raising the singing point and increase the volume required.

2.4 Operation During Testing and Performance

Due to the large number of variable factors which will be encountered in the different types of installation, it is not possible to set up a routine which will completely cover the operation of all installations. In this division an attempt will be made to cover the important features which should be of use in giving efficient operation and service.

The nature of a Public Address installation is such as to require considerable preparation in order to give satisfactory service so that ample time should be allowed, say, several days, depending upon the importance of the service to be given, for testing transmitters and projectors, distribution, quality and any other characteristics of the system as a whole. In addition, it is essential to hold several complete rehearsals, the purpose of these being to coordinate such switching as will be necessary, the passing of signals and instructions over telephone circuits, or instructing speakers and singers as to their positions relative to the transmitters and for obtaining volume data for different persons. In some cases it will be

impossible to obtain the same speakers for rehearsals that will be present during the service and if this is true other performers should be substituted so that the entire program may be carried out

It is also desirable to maintain the same organization for rehearsals and preliminary tests as will be used for the actual service contemplated. In this way it will be possible to find out the weakest parts of the system and correct them so that the chance of failures during the loudspeaker service which may involve delays for a large number of people and considerable disappointment and expense may be eliminated.

Furthermore, it should be remembered that when an audience is present, the system should never be working until those located at the speaker's stand are ready to begin the program, since some remarks may get into the projectors which have no bearing on the program itself. When more than one transmitter is used, it is particularly desirable to provide efficient means for the control forces and the speakers to synchronize their efforts. In some cases miniature colored lamps operated by a push button or a key will be found useful, but they should not be made too elaborate.

2.41 Organization of Control Forces

There are in general two functions of the control forces: (1) maintenance of satisfactory volume in all parts of the audience while the program is being carried on and (2) operation of switches to synchronize the use of the system with the program. The first is taken care of by certain Observers and a Control Operator who are in constant communication with each other by means of a telephone circuit and the second is accomplished through the use of another telephone circuit between the Speaker's Stand or Platform, a Switching Operator and a Long Lines Control Operator if Long Lines are used.

Drawing No. 906-861 shows an organization diagram using these two telephone circuits. As illustrated in this drawing, the Observers report to a Chief Observer over an auxiliary telephone circuit, while the Chief Observer is the only Observer in direct communication with the Control Operator. This use of a Chief Observer is suggested where a large number of observers are required, but where only a few observers are used they may all report directly to the Control Operator, eliminating the auxiliary telephone circuit and the position of Chief Observer.

In general, the Control Operator and Switching Operator are located close to each other. If, however, due to local conditions, it is necessary to locate the switching apparatus several feet from the amplifier equipment, it may be necessary to use a telephone circuit between these two operators.

It is desirable to locate the Long Lines control panel several feet from the switching and amplifier panels in order to reduce confusion as much as possible in the control room, since considerable talking and telegraphing is necessitated in lining up the Long Lines circuit. It may also be desirable to use a telephone circuit between the Long Lines Control panel and the long distance test room in order to facilitate lining-up the circuits.

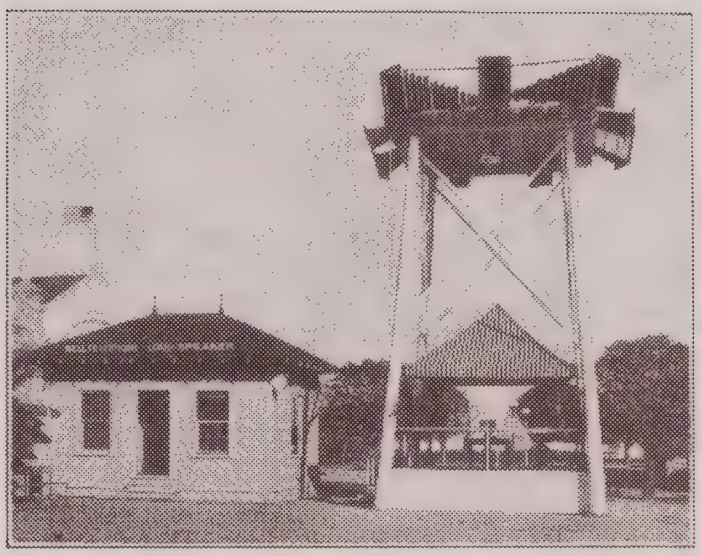
It is, of course, obvious that no Long Lines Control Operator will be required when Long Lines circuits are not used. If no emergency equipment is provided and no Long Lines involved, the Switching Operator can be eliminated. It is quite possible, for a small performance, that the Control Operator could take care of operating the complete system alone.

2.42 Duties of Control Forces

It is desirable, during rehearsals, and very essential during the performance, to reduce the confusion in the control room to a minimum. To this end, all those not directly concerned in the operation should be excluded from the control room. It is also important that the cooperation between the various operators be as close as possible, in order to insure a smoothly running organization.

2.421 Control Operator. During opera-

Continued on p. 67



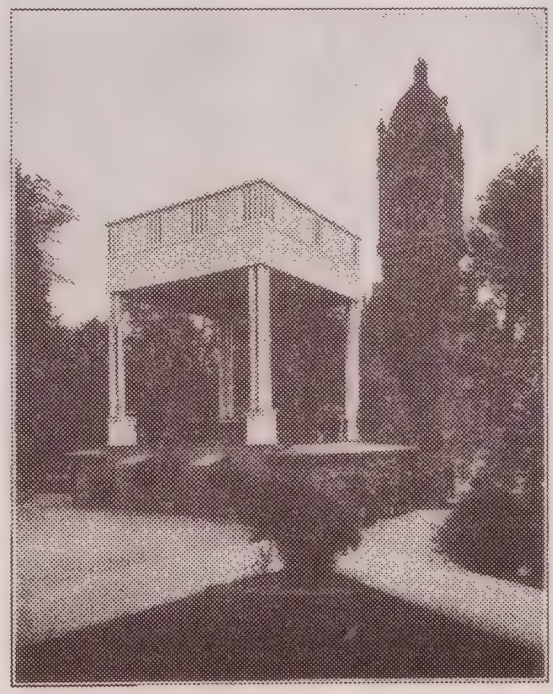


Plate 1. Typical outdoor installations

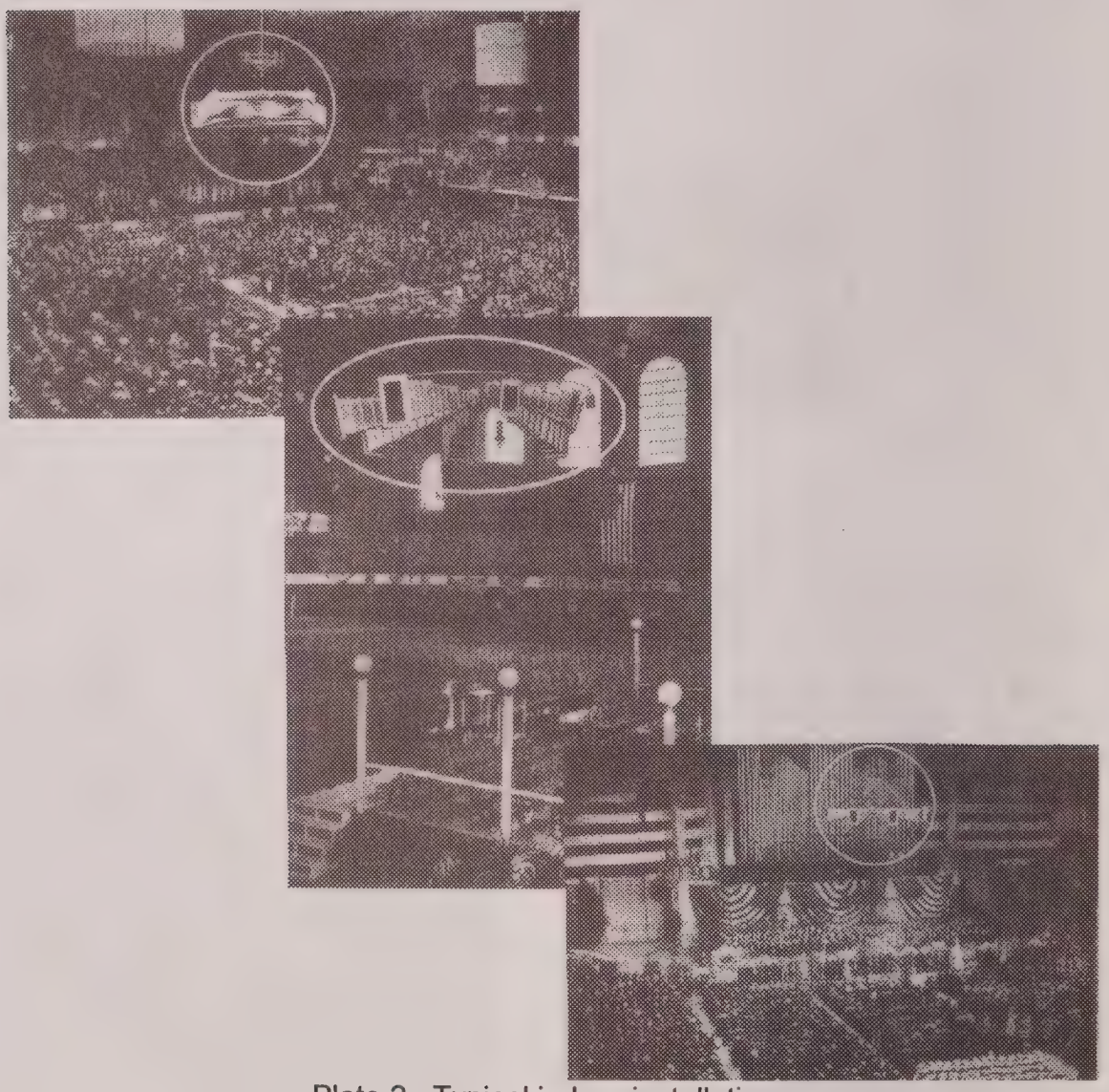


Plate 2. Typical indoor installations

(The bottom photo shows the Civic Auditorium, as the San Francisco end of the Armistice Day ceremony of 1921. - TCA ed.)

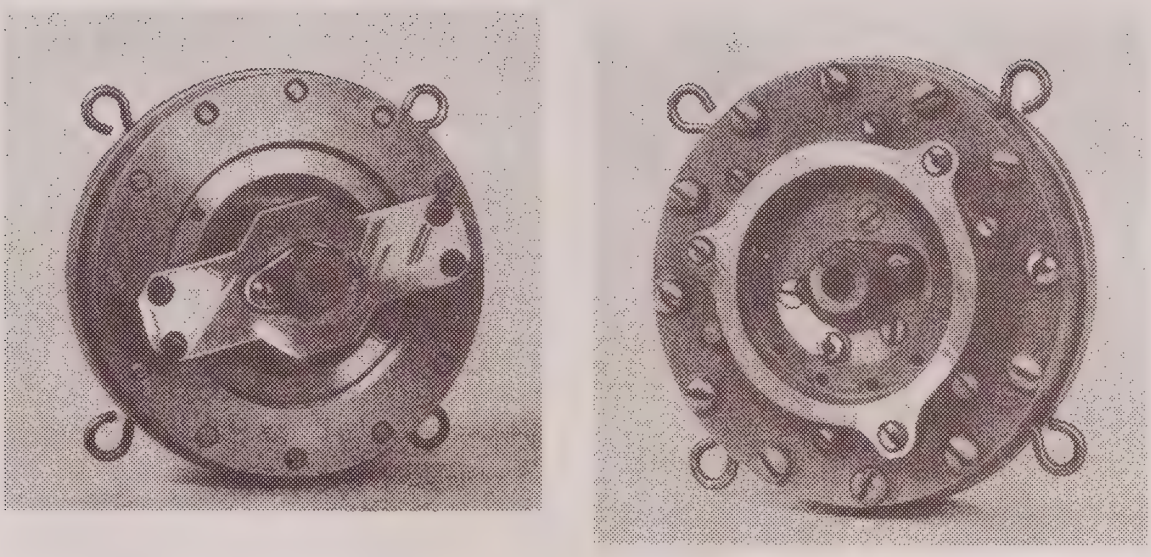


Plate 3. Front (L) and back (R) views of No. 369-W transmitter

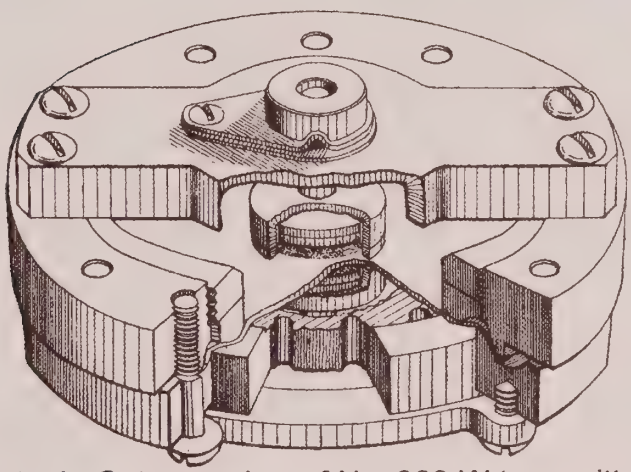


Plate 4. Cutaway view of No. 369-W transmitter.

Plate 5. Views of No. 1-A transmitter mounting with transmitter suspended in place

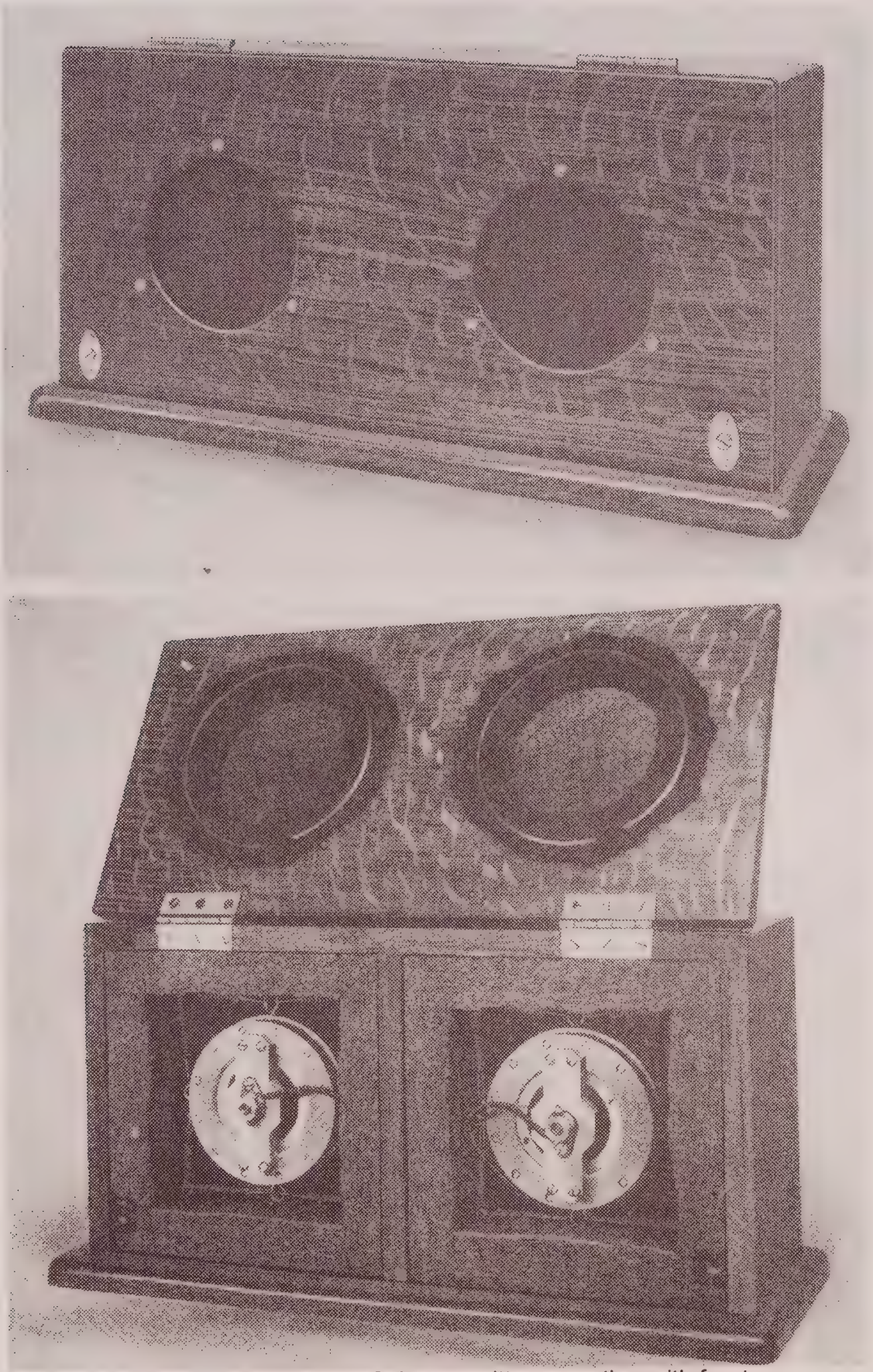


Plate 6. Views of No. 2-A transmitter mounting with front closed, and with front open and transmitters in place

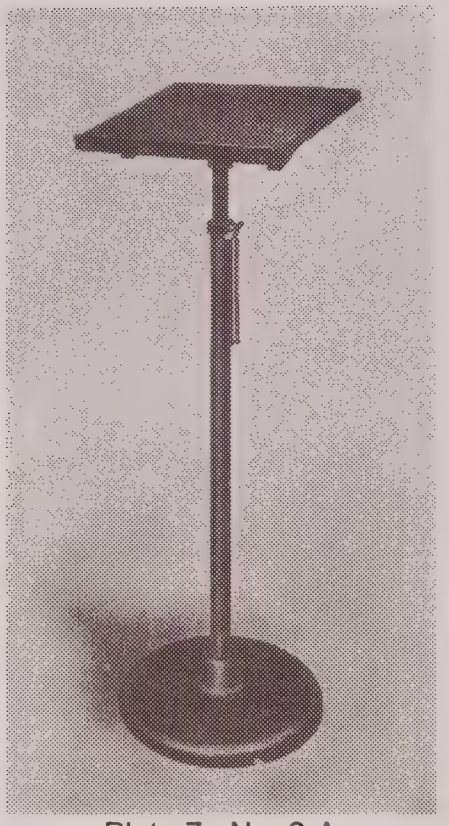


Plate 7. No. 2-A pedestal

Plate 8. No. 1-A pedestal with no. 2-A transmitter mounting in place

Plate 9. Combination of reading stand and transmitter pedestal, with transmitter box

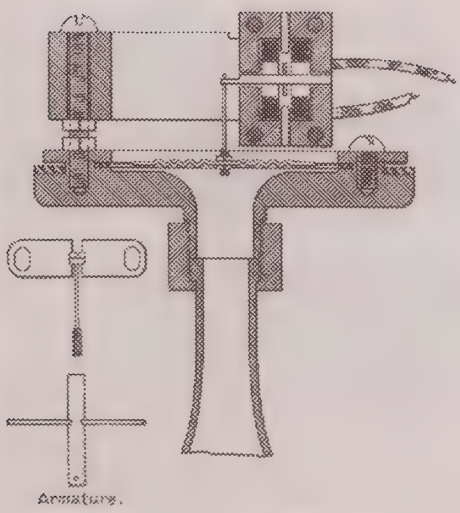
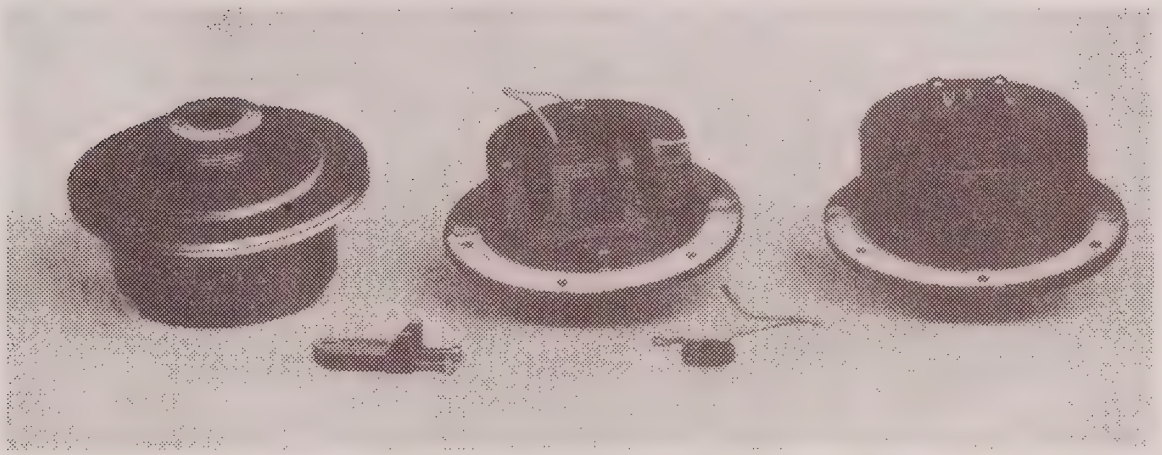


Plate 10. Schematic cross-sectional view of receiver



Views showing the No. 196-W receiver with case in place and with case, one pole piece and one coil removed

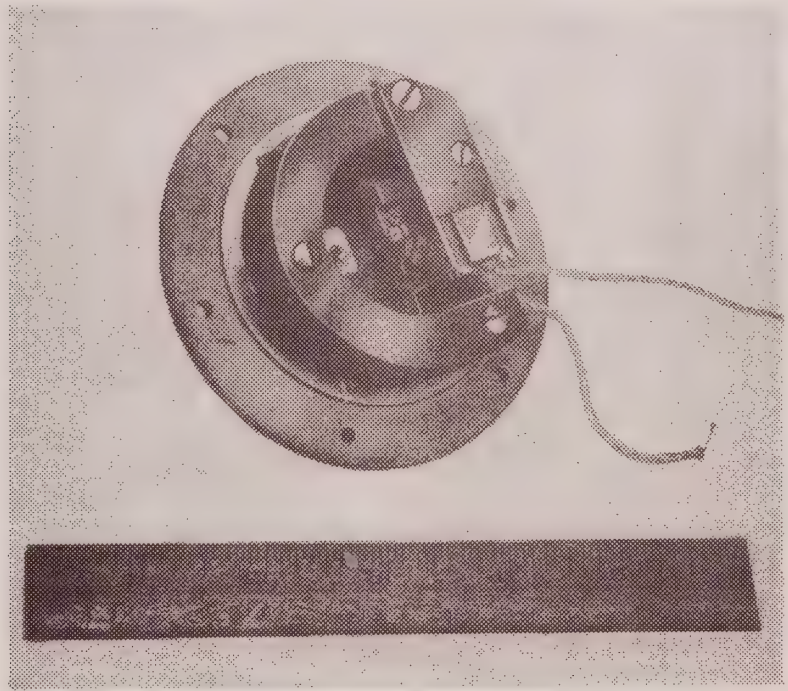


Plate 11. View of back of the No. 196-W receiver with case removed

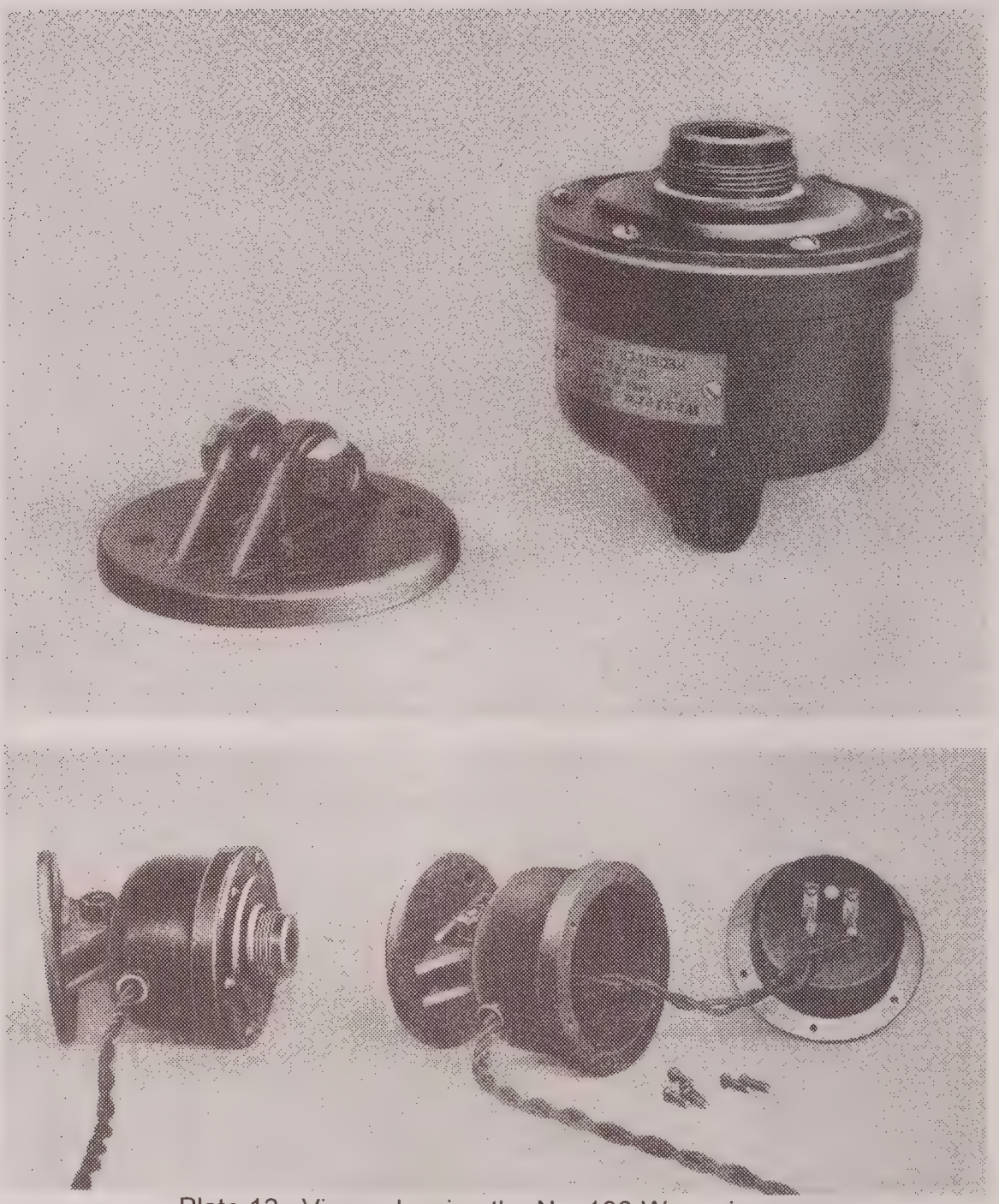


Plate 12. Views showing the No. 196-W receiver as used with a No. 3-A receiver holder and 8A bracket

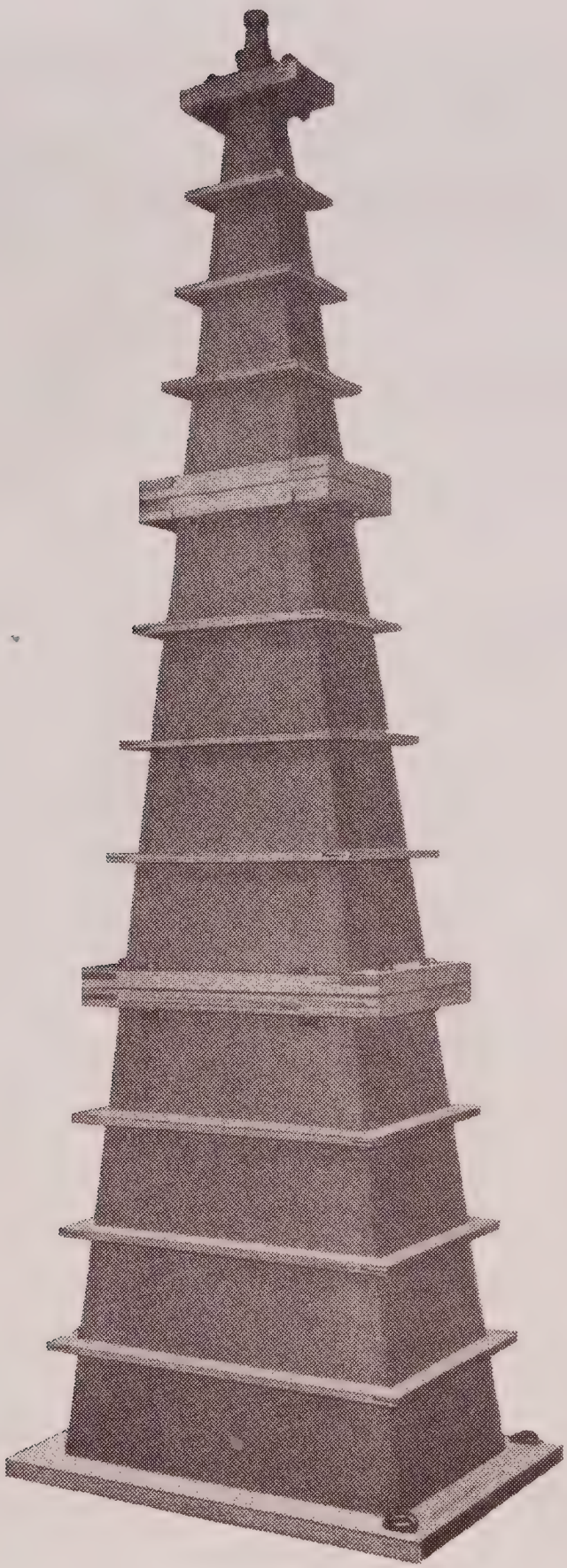
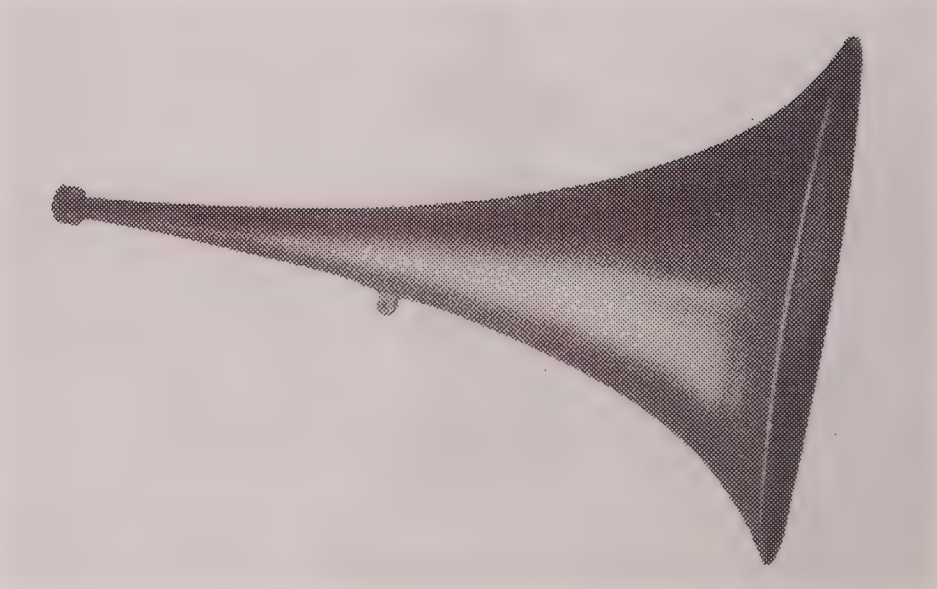
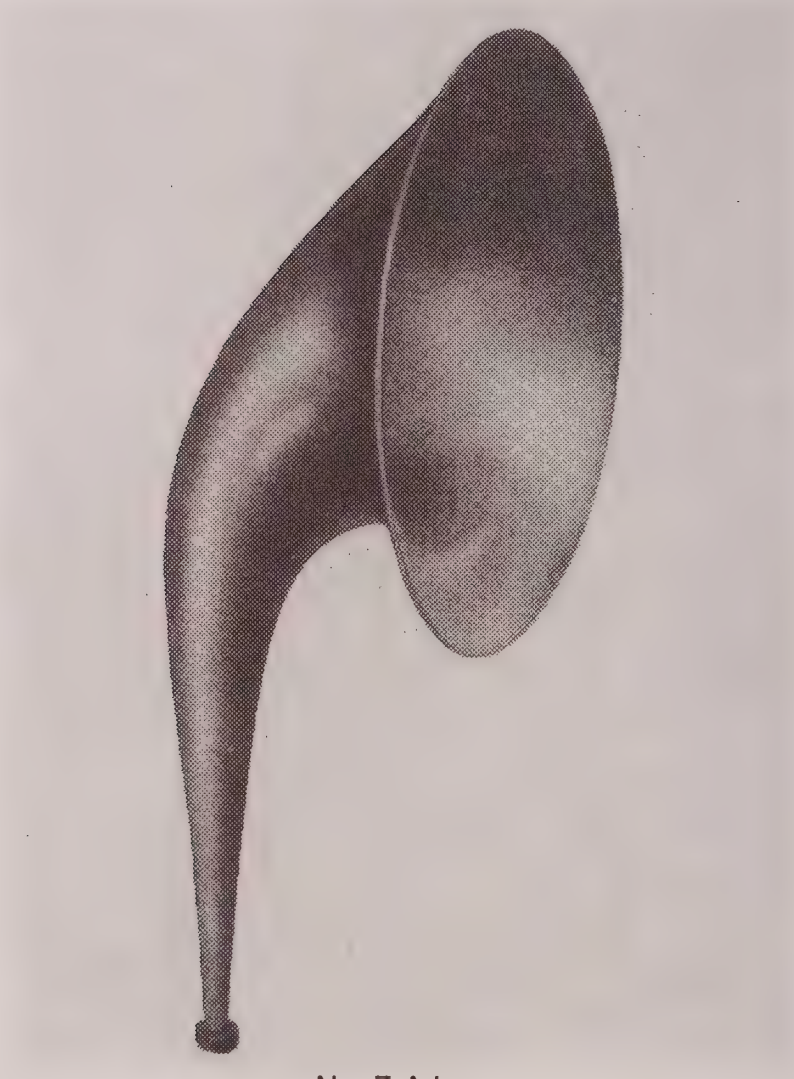


Plate 13. The No. 5-A horn



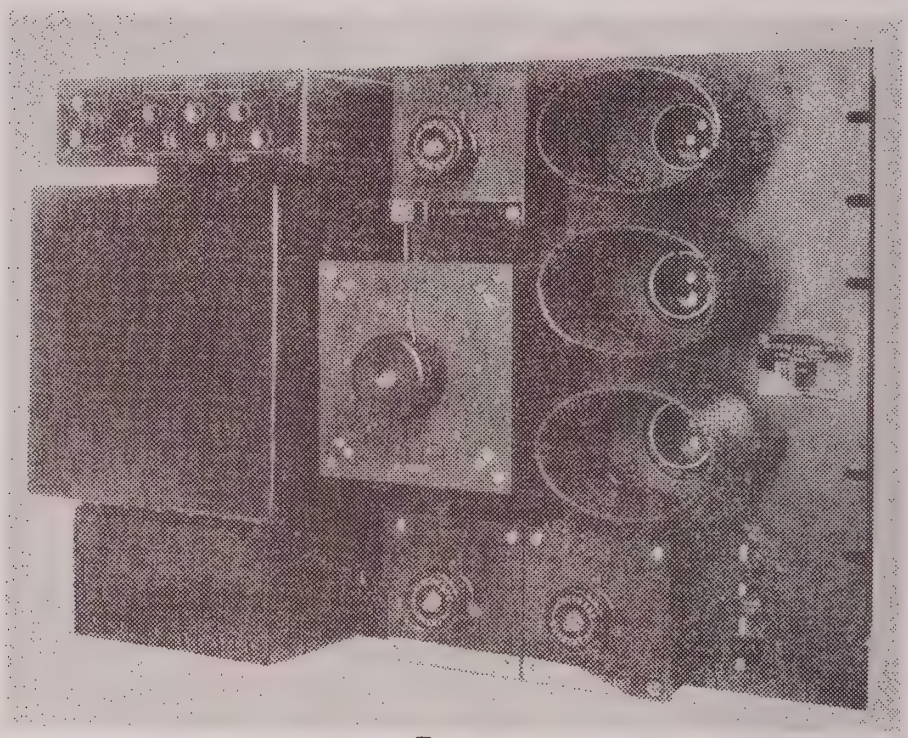
No. 6-A horn



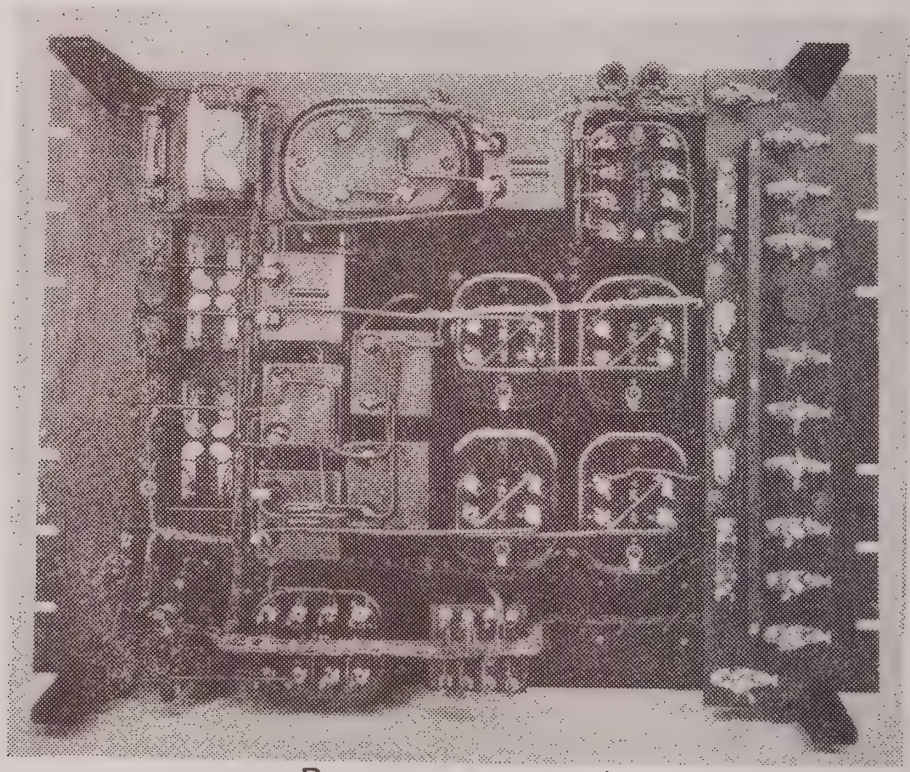
No. 7-A horn

Plate 14. The Nos. 6-A and 7-A horns

Plate 15. The No. 6-A horn and No. 196-W receiver mounted on a No. 3-A pedestal

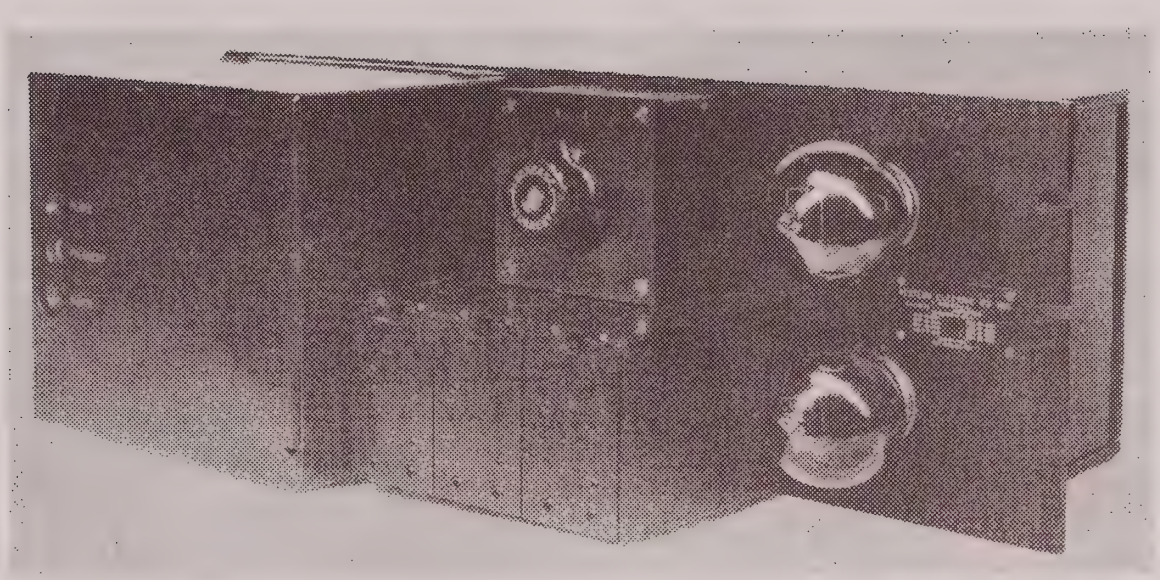


Front

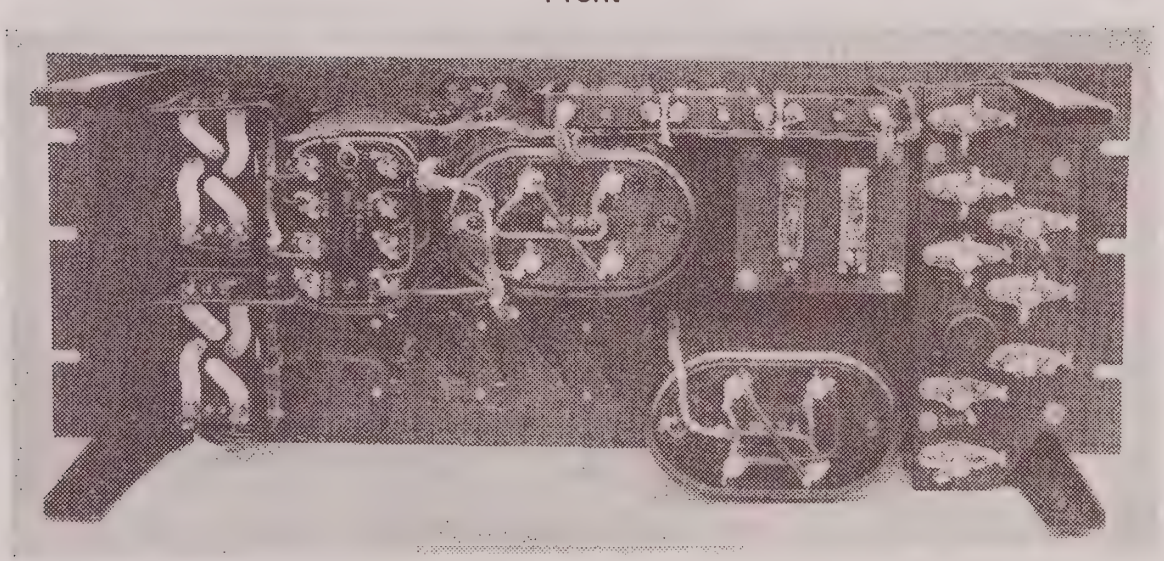


Rear - cover removed

Plate 16. No. 8-A amplifier



Front



Rear - cover removed

Plate 17. No. 9-A amplifier

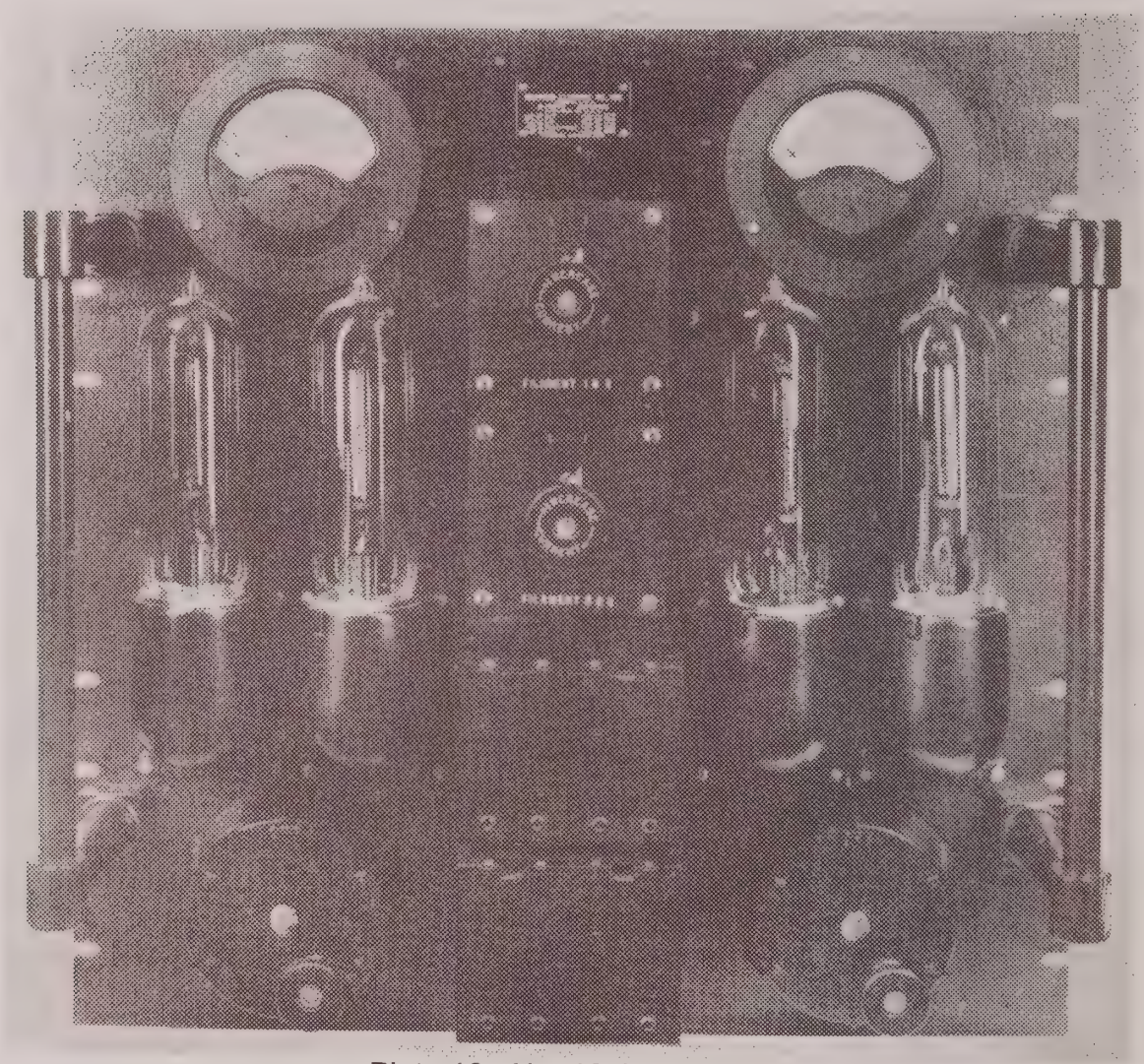
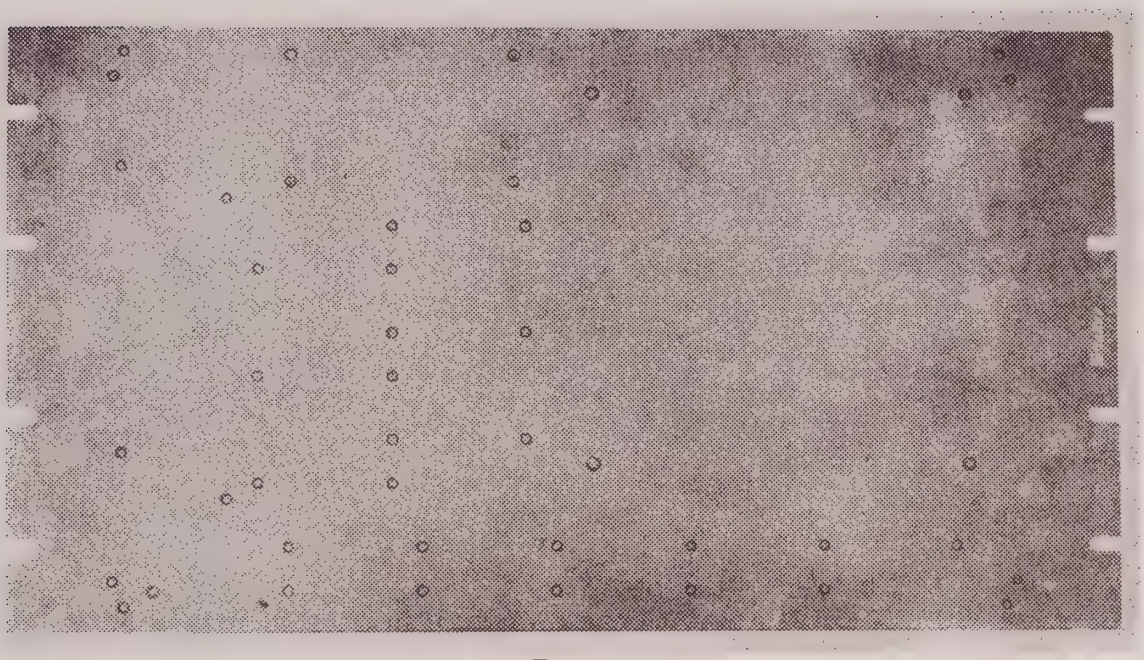
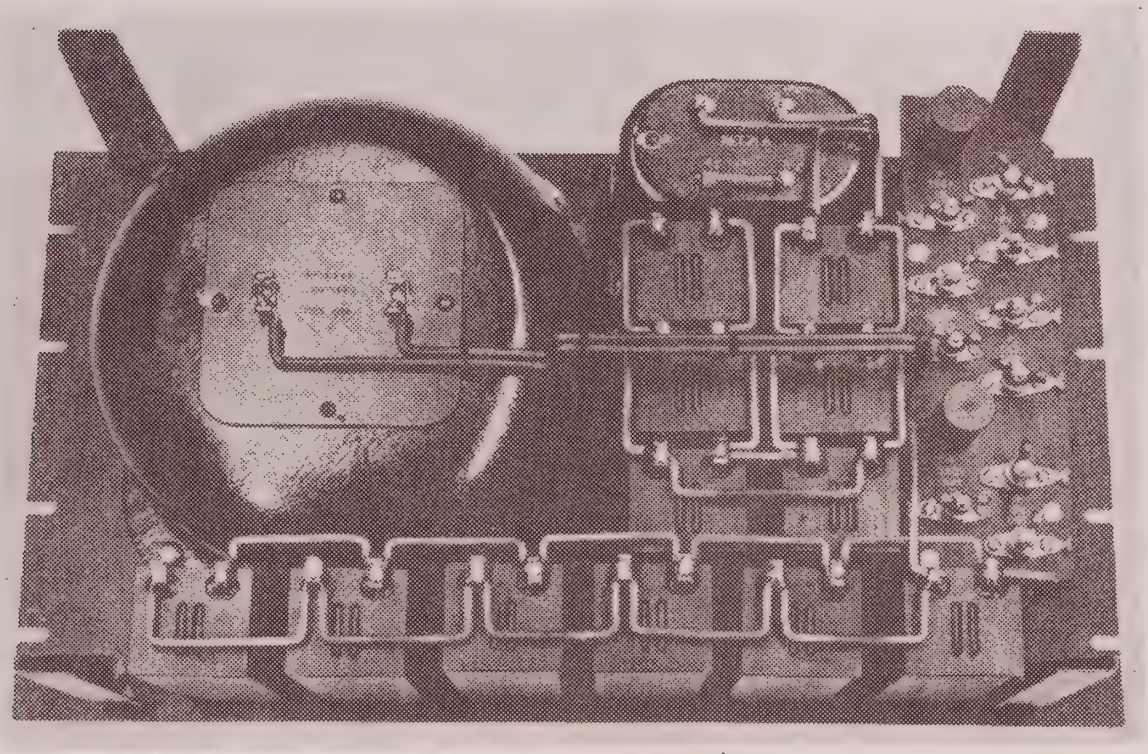


Plate 18. No. 10-A amplifier

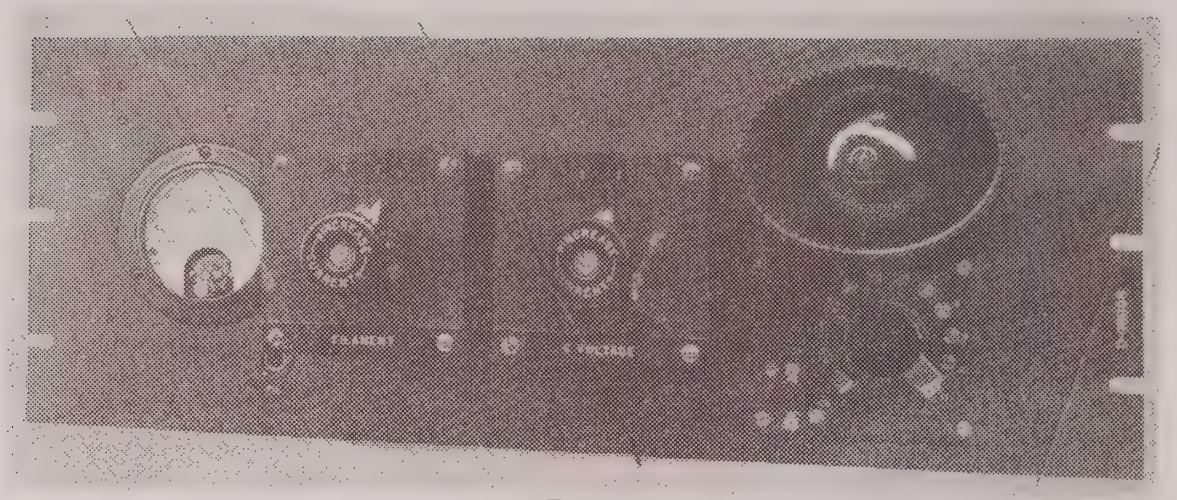


Front

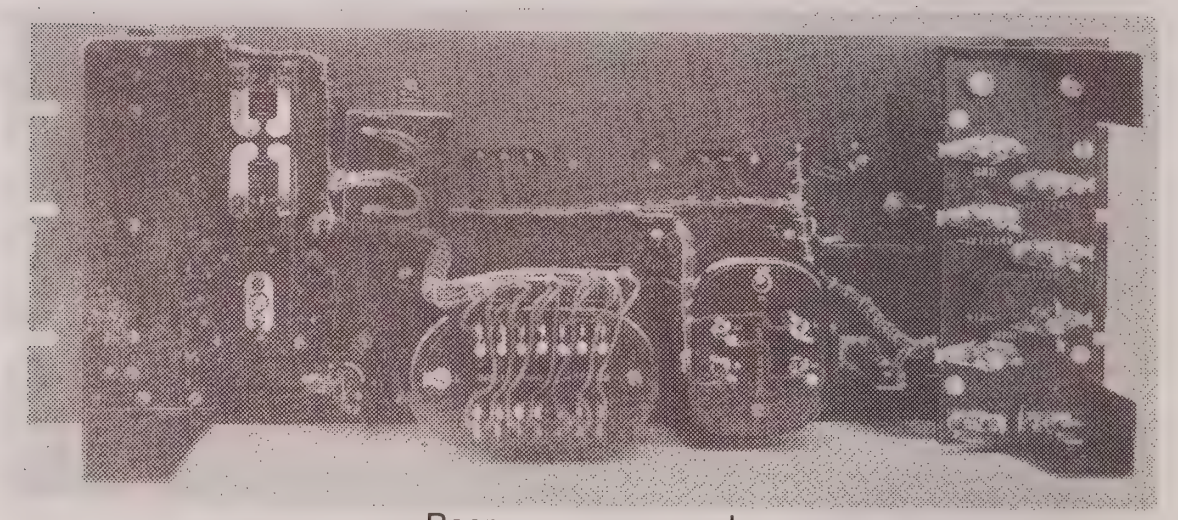


Rear - cover removed

Plate 19. Filter panel for use with motor-generator set

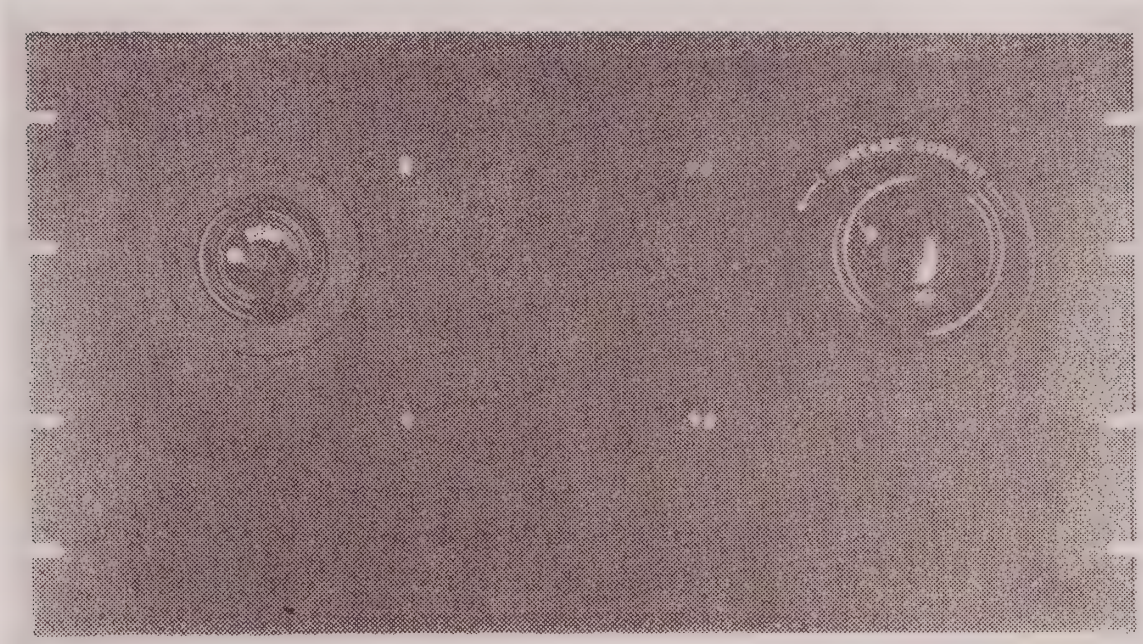


Front

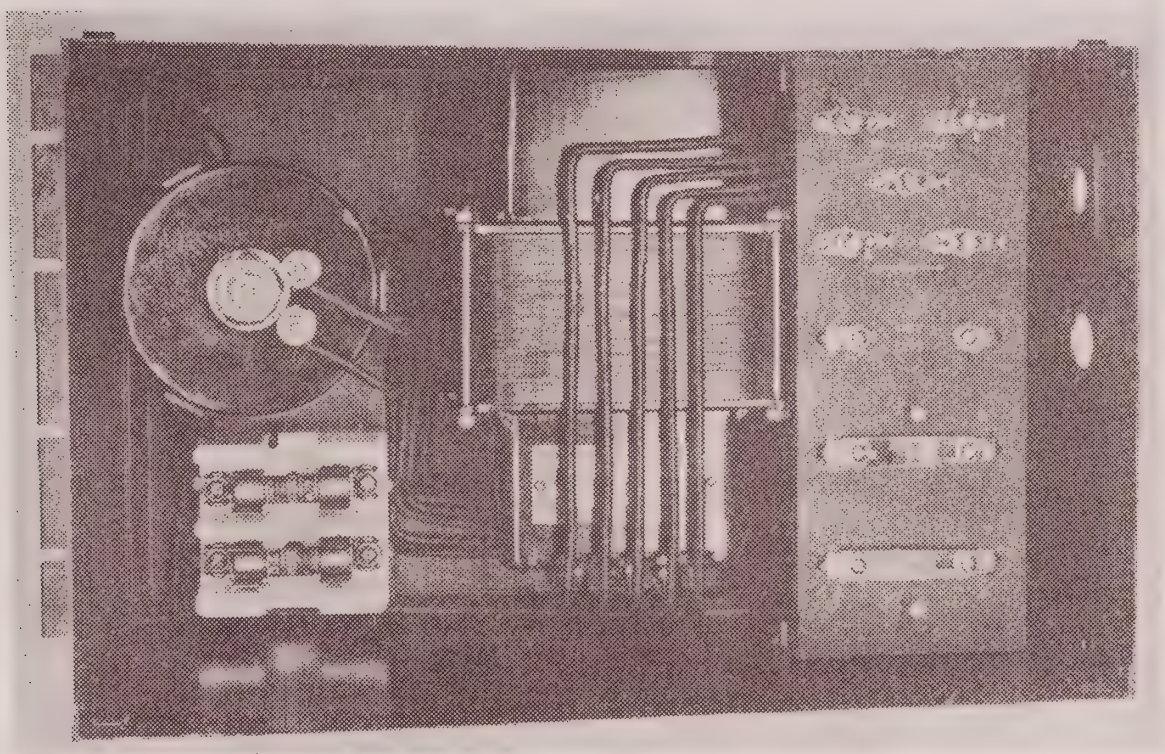


Rear - cover removed

Plate 20. Volume indicator panel

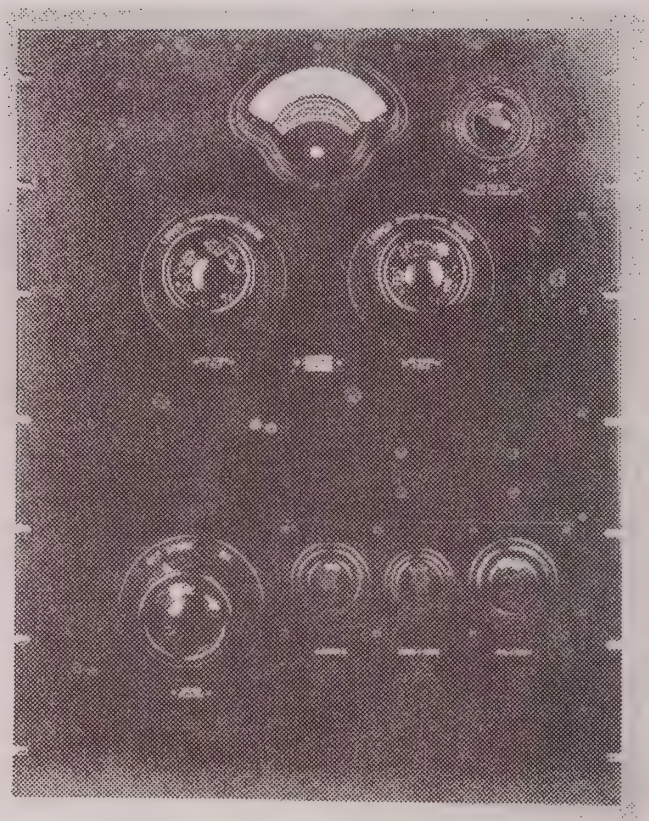


Front

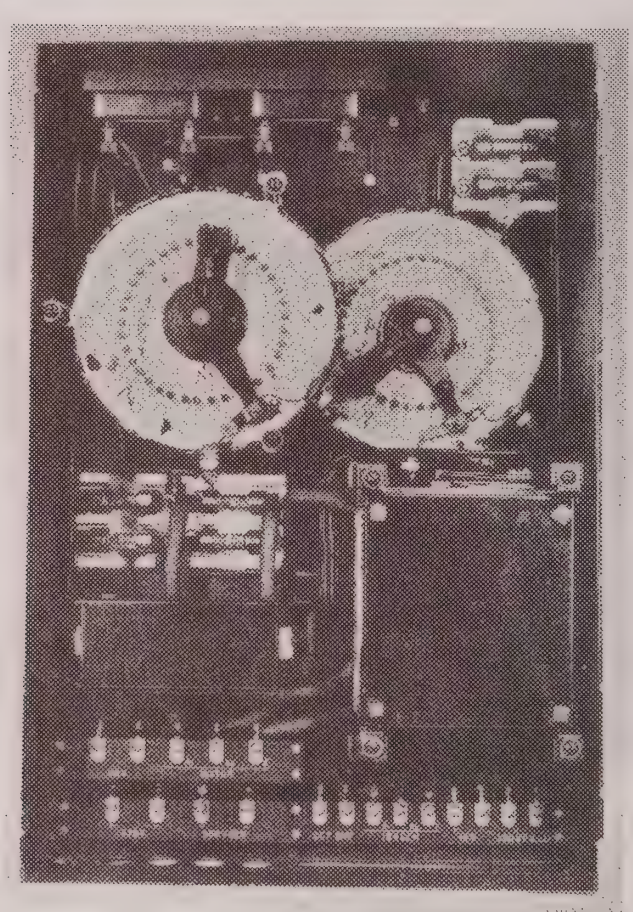


Rear - cover removed

Plate 21. A. C. filament supply panel

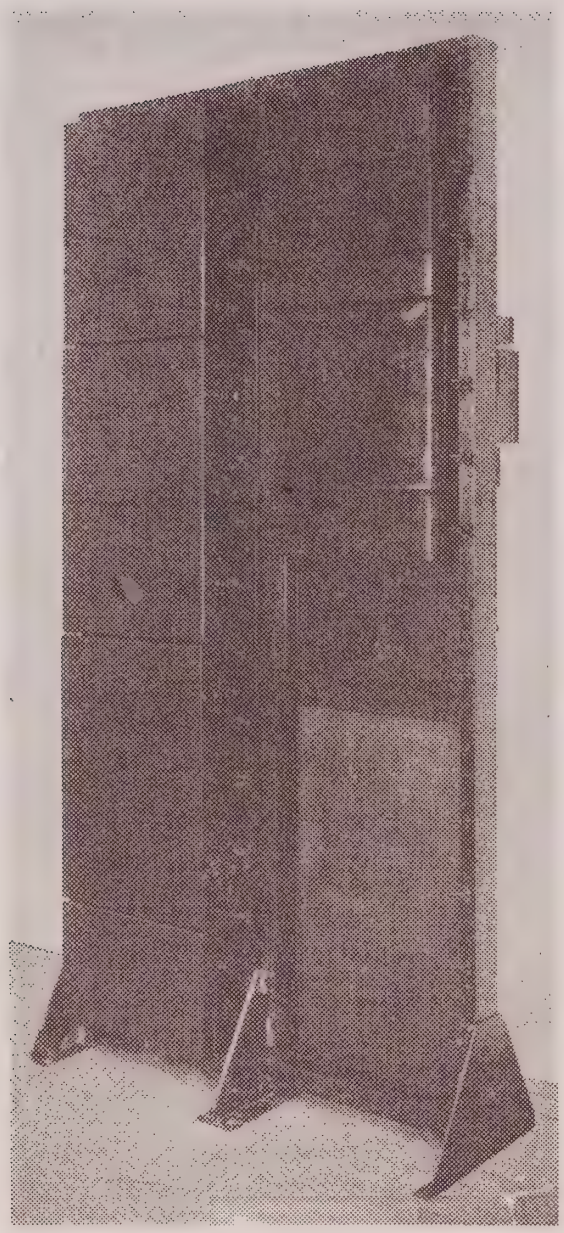


Front

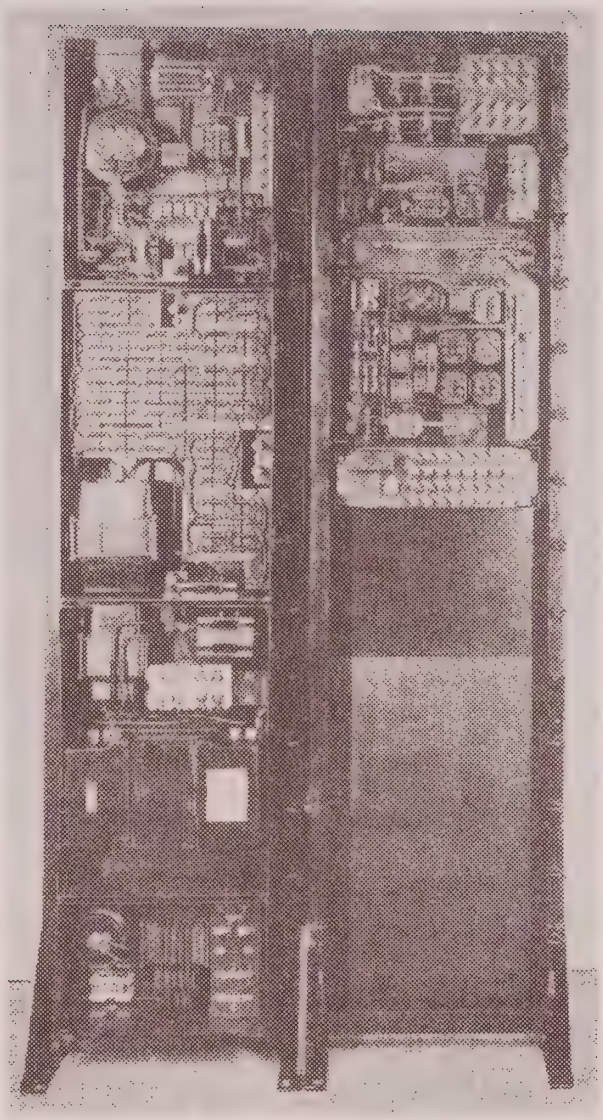


Rear - cover removed

Plate 22. Power switching panel

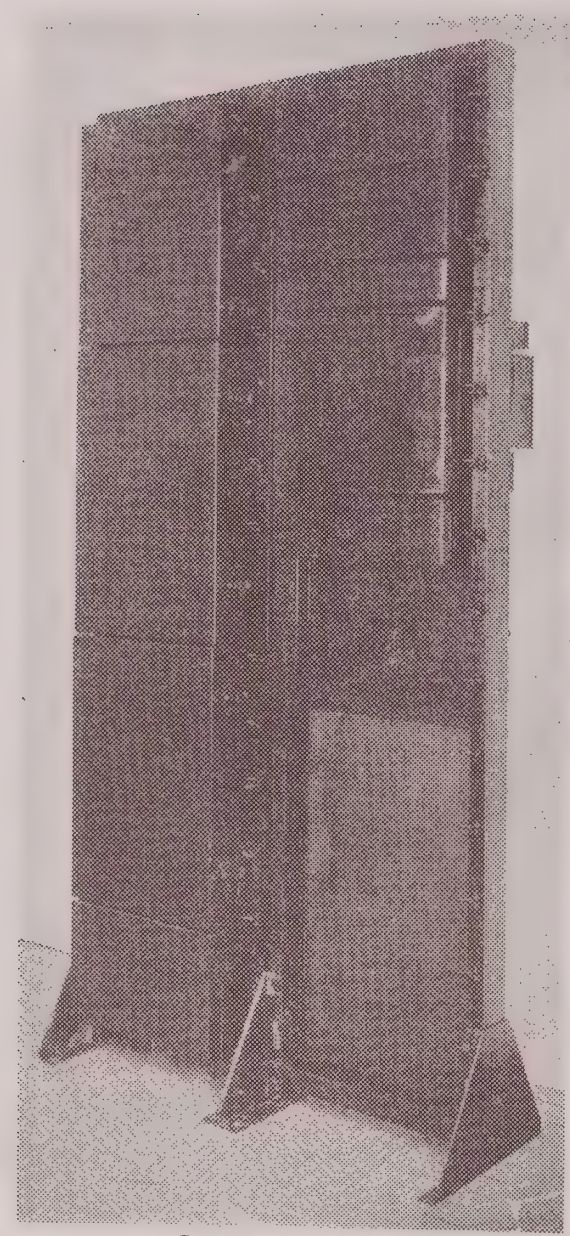


Covers on

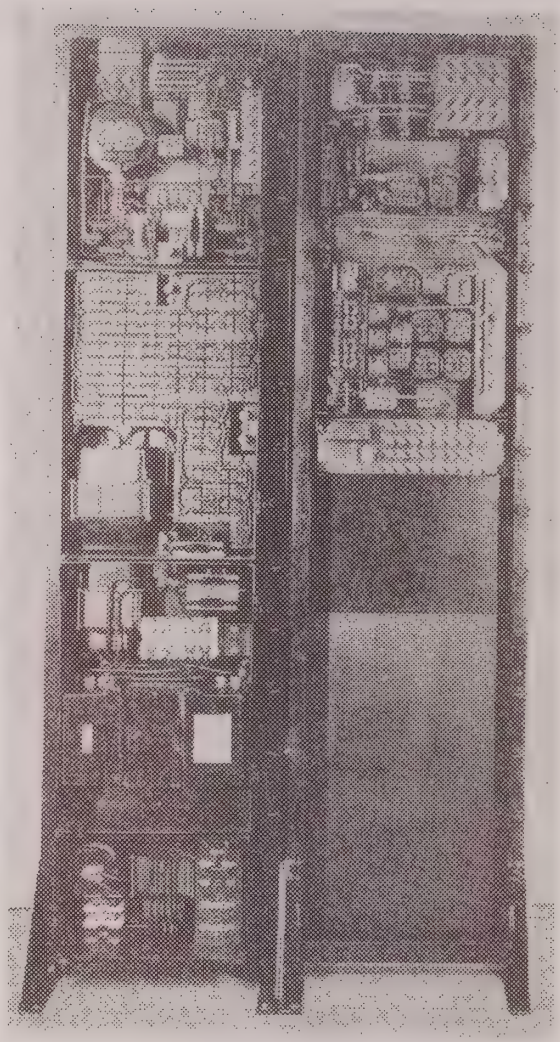


Covers removed

Plate 23. Typical control room rack assembly



Covers removed



Covers on

Plate 24. Typical control room rack assembly - rear view

Continued from p. 46

tion, the Control Operator has the greatest responsibility for the success of the performance. He can be considered the nerve center of the whole system. It is therefore apparent that this operator should be a man who can think and act quickly, and. remain reasonably cool and collected under trying circumstances. He should have full responsibility for making all gain and volume adjustments. In making these adjustments, he should depend largely on the volume indicator as a guide in regulating the volume. In general, he will be able to correct for volume changes due to the speaker varying his distance or voice before these changes actually result in a volume change at the projectors which is sufficiently great to be noticed by the observers. He will, of course, have to regulate the volume as requested by the observers.

2.422 Switching Operator. The Switching Operator should have complete charge of all switching necessary except switching of power apparatus. It should be his duty to switch in the different units of apparatus as required, and to switch in emergency equipment when necessary. The connection of the Long Lines to the amplifiers should also be under his control.

2.423 Power Operator. The Power Operator should be responsible for the operation of the generator sets, rectifier sets, and seeing that the batteries are properly charged, and the proper voltages are applied to the amplifiers. He should also be responsible for switching any emergency power equipment, as required.

2.424 Platform Man. The duties of this operator will vary considerably. His main function will, in general, be to keep in touch with the Switching Operator, to advise him when to turn the system on and off and of the changes required for a particular program.

2.425 Observers. Observers, in general, should not be too hasty in requesting a change in volume, as small fluctuations of short duration may occur from time to time for which it is not necessary to regulate. However, when it is necessary to change the volume they should., in passing their requests for this change, name the number of the projector or group of projectors on which change is desired, as, for instance, "Raise Projector No. 7 one step." In this manner the work of the Control Operator is simplified.

2.426 Long Lines Control Operator. This operator should have complete charge of the Long Lines circuits up to the time he turns these circuits over to the Switching Operator. It is his duty to see that they are properly lined up, and that the transmission is satisfactory. He should also make sure, just previous to turning the circuits over, that all repeater attendants are monitoring the particular circuit which is to be used. If several circuits are to be lined up, it may require the services of two or more men, but in order to avoid confusion and mistakes, there should be one man in charge who would pass on the condition of the circuit before turning it over. The Switching Operator should be advised regarding the equivalent of the circuit, and he will in turn advise the Control Operator who can make the necessary gain adjustments.

2.43 Volume Adjustments

In the foregoing paragraph the necessity for maintaining satisfactory volume, while keeping within the limits of this system, has been emphasized. The methods for doing this during testing and operation will now be discussed.

2.431 Reports of Observers. In general, these are the most reliable indications of the satisfaction produced by the use of the Public Address System. If all the observers require more volume, the potentiometer of the transmitter amplifier should be increased or the settings of all projectors on the volume control panel should be correspondingly raised.

If observers in a certain location only require more volume due to local interference or the effects of a strong wind, only the volume control settings of the projectors supplying that locality should be raised and

the effect of these changes should be taken care of as explained under the operation of the volume indicator.

2.432 Volume Indicator. The volume indicator is essential in determining the margin of operation in the system, in maintaining constant volume for different speakers and in maintaining constant volume when individual projector settings are changed.

If the power required for a system is known, the amplifier setting may be found from the gain calibration and the volume indicator used to check this power level by connecting it to the volume control panel and setting its dial switch and the switch on the volume control panel so that the sum of these two settings in miles is equal to the output level desired. For example, if the desired output power of the amplifier is 34 miles, set the switch on the volume control panel to the position marked "high" and set the dial switch of the volume indicator on Step 5 which, according to the table given in division 1.14, indicates 14 miles on the volume indicator, the other 20 miles being obtained on the switch on the volume-control panel. The standard deflection on the volume indicator should then be obtained when the amplifier is delivering the proper output level.

If the power output is not known, it may be determined by adjusting the amplifier gain by means of its potentiometer until the volume is considered satisfactory by the observers and then adjust the volume-indicator dial switch until the standard deflection is obtained. The switch on the volume control panel should be operated to either the high or low position depending on which is necessary to give the standard deflection on the volume indicator. For example, if the switch were on a position marked "low" and the volume indicator on step 3, the power output of the amplifier from the table in division 1.14 should be 18 miles.

The difference between the operating power output of the amplifier and the maximum output obtainable may then be noted as an indication of the amount the gain may be raised before overloading of the amplifier takes place.

To use the volume indicator in maintaining constant volume for different speakers, the Control Operator should note the galvanometer deflection when changes in the speaker's voice or in the program occur. If the standard deflection is exceeded the amplifier gain should be reduced until the standard deflection is reached and vice versa.

Whenever individual projector settings are changed due to requests from certain observers, the load impedance may be changed and the amplifier output correspondingly varied. The galvanometer deflections of the volume indicator should be noted carefully during such changes and, if necessary to maintain the standard deflection, the amplifier gain should also be changed.

The volume required from the projectors may be different for different acoustical conditions, as explained elsewhere, so that it is to be expected that the amplifier gain will have to be increased several miles when an audience is present over what it would be if there were no audience. In order that the volume indicator should give the standard deflection for different acoustical conditions, the corresponding change should be made on the dial switch of the volume indicator as the gain is increased. In other words, the settings of the dial switch on the volume indicator and the potentiometers of the amplifier will not be the same during rehearsals as will be required during operation with an audience present. The adjustment can be made while the first speaker is talking by increasing the amplifier gain until the observers are satisfied with the volume, and then reducing the dial switch of the volume indicator until the standard deflection is reached. This standard deflection should be maintained until some change in acoustical conditions or projector load makes it necessary to be changed.

2.433 Monitoring Projector. In addition

to the foregoing methods for maintaining satisfactory volume, the monitoring projector mounted in the control room should give a fairly good indication of the larger effects due to changes in speakers, etc., or any troubles which may develop.

2.434 Space-Current Measurements. As an additional indication of whether or not the system is being overloaded, care should be taken at all times during tests and operation that the space current fluctuations in the last stage of the various amplifiers in the system do not exceed the following amounts:

Amplifier	Normal Space Current	Fluctuations
#8-A or #11-A (130 volts)	7 milliamperes	1 milliampere
#8-A or #11-A (350 ")	34 "	4 "
#9-A (each tube)	34 "	4* "
#10-A (4 tubes)	300 "	30* "

*Notes: These fluctuations will be reduced about one-half if the plate potentials are supplied from a steady source with low internal impedance.

If the above fluctuations are exceeded on an average of once every 10 seconds, it indicates that the output power of the amplifier is great enough to overload the vacuum tubes and produce distortion and the amplifier gain should be reduced.

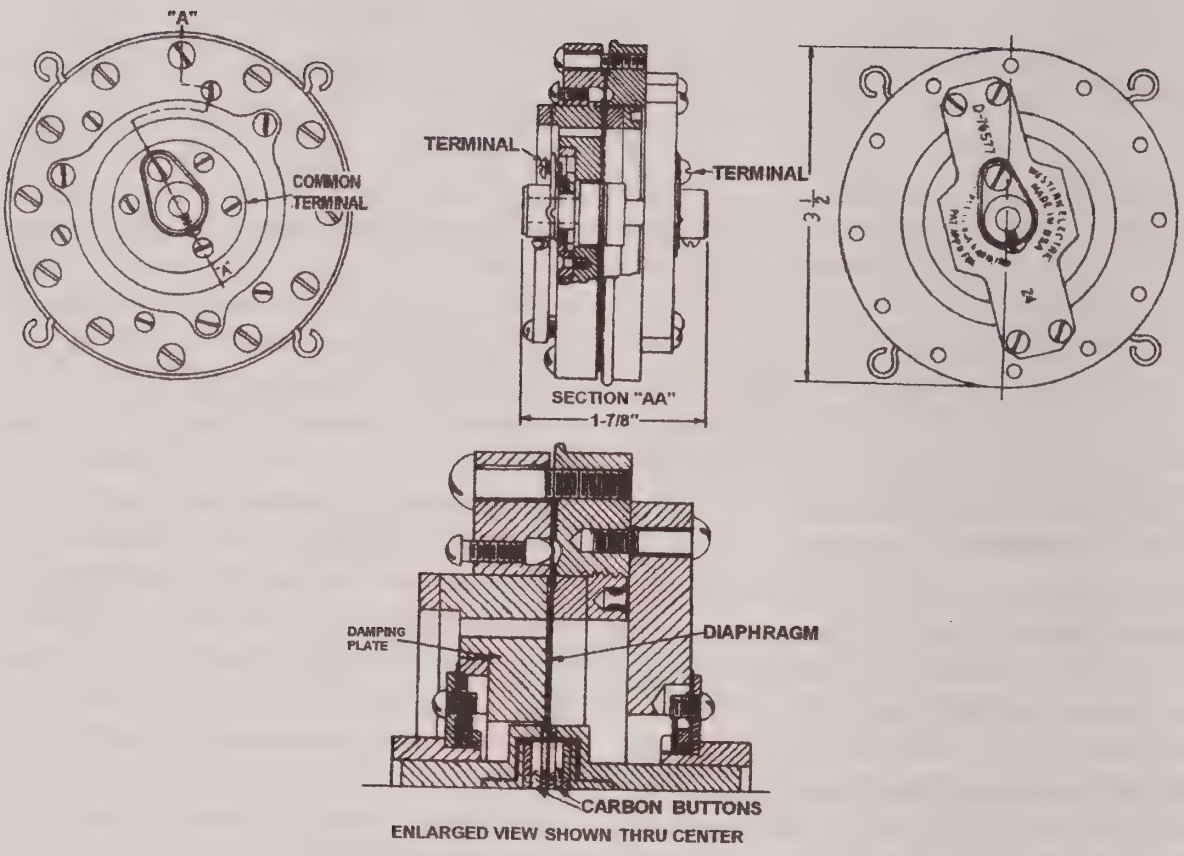
2.44 Keeping of Records

To assist the control forces in rapidly setting up the system, adjusting the amplifier gains and volume-control settings, records of the amplifier settings for test conditions and during the performance should be made and kept readily available. Records properly kept will be found of great assistance in the operation of the system. Several forms are given here as samples of what should be included in these records. It is not necessary that the exact form as given here be followed, although it will be found that these forms include all the essential information necessary.

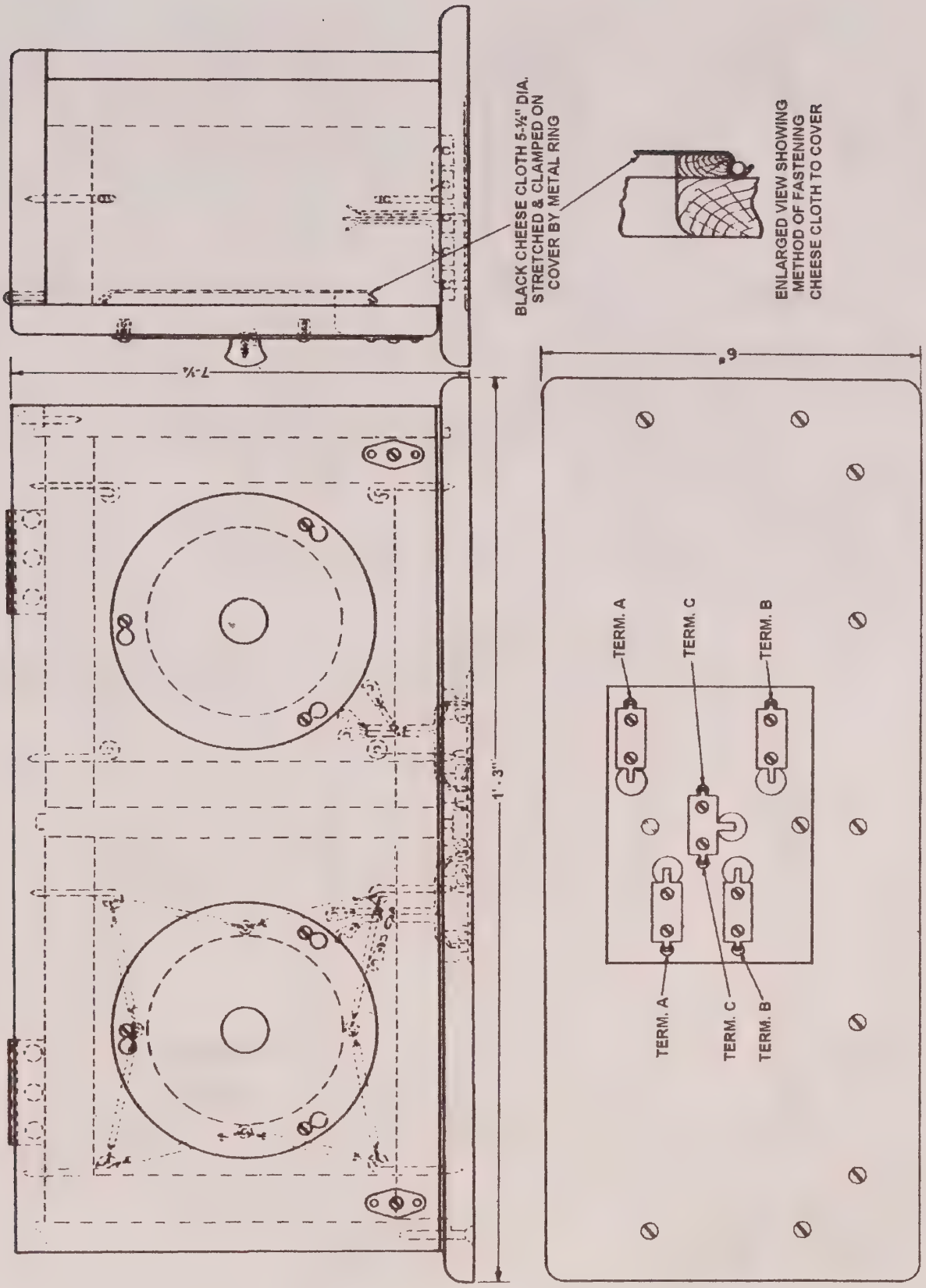
2.441 Current and Voltage Measurements. On Form 1, a table is shown which gives current limits and normal potentials with spaces for noting the values measured. Where voltages or currents are adjustable, the adjustments should first be made, and the adjusted values recorded, as the steps on the rheostats are not always fine enough to allow adjusting to the normal values. It will be noted that Form 1 includes the complete record for routine tests.

2.442 Calibration of Amplifiers. On this sheet is given a tabulation for the gain calibration of the amplifiers for the particular combination of amplifiers involved. The data for this sheet will be obtained on the initial tests. This sheet should be posted in a conspicuous place where the Control Operator may see it at all times.

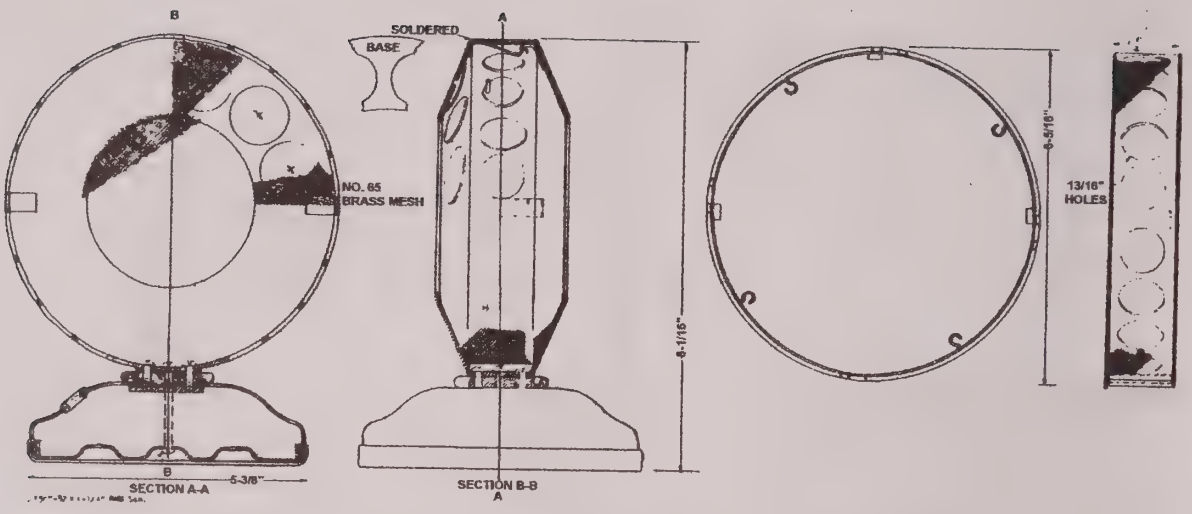
2.443 Testing and Service Record. This sheet constitutes a log sheet containing all necessary information relative to the amplifier and volume control settings for various conditions, both during testing and during performance. One copy of this should always be posted in front of the Control Operator.



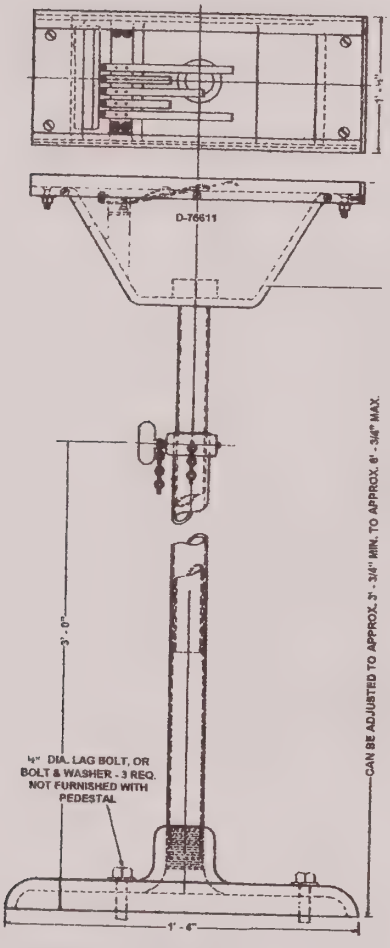
Drawing 197-B-22, 7-3-20 - Transmitter per D-76577


BLACK CHEESE CLOTH 5-½" DIA. STRETCHED & CLAMPED ON COVER BY METAL RING
ENLARGED VIEW SHOWING METHOD OF FASTENING CHEESE CLOTH TO COVER
1'-3"
TERM. A
TERM. C
TERM. B

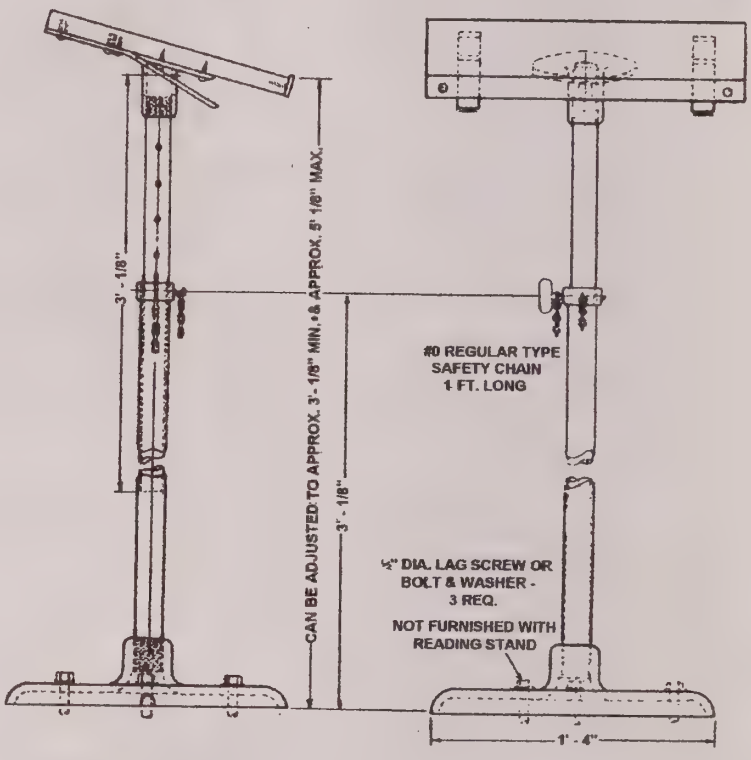
Drawing 197-B-23, 7-23-22 - Transmitter box D-76612 assembly



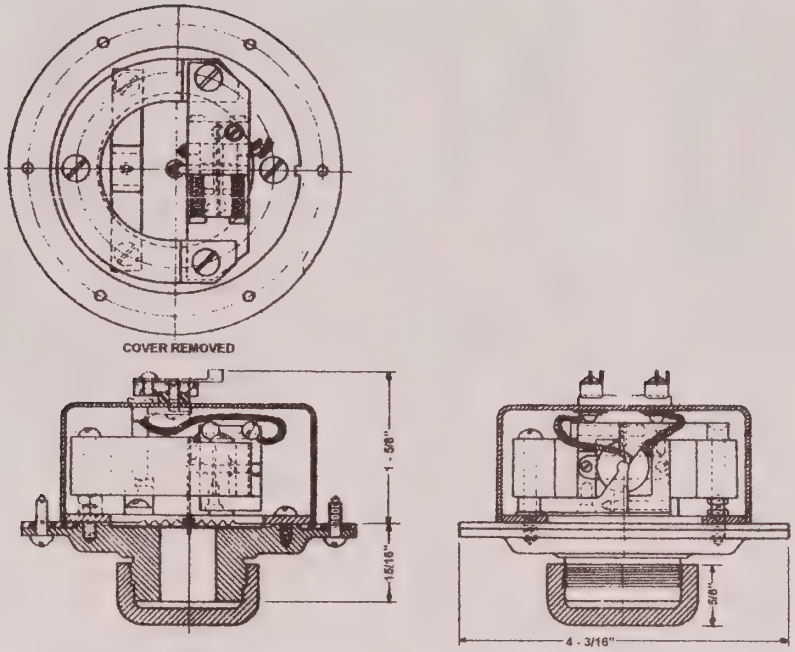
Drawing 144-A-42 - Transmitter mounting per D-76534


D-76611
3' - 0"
½" DIA. LAG BOLT, OR
BOLT & WASHER - 3 REQ.
NOT FURNISHED WITH
PEDESTAL
CAN BE ADJUSTED TO APPROX. 3' - 3/4" MIN. TO APPROX. 6' - 3/4" MAX.
1' - 6"

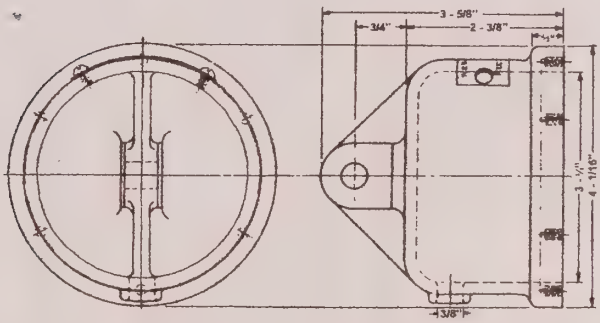
Drawing 144-A-49, 7-3-22 -
Transmitter pedestal
D-76611 assembly



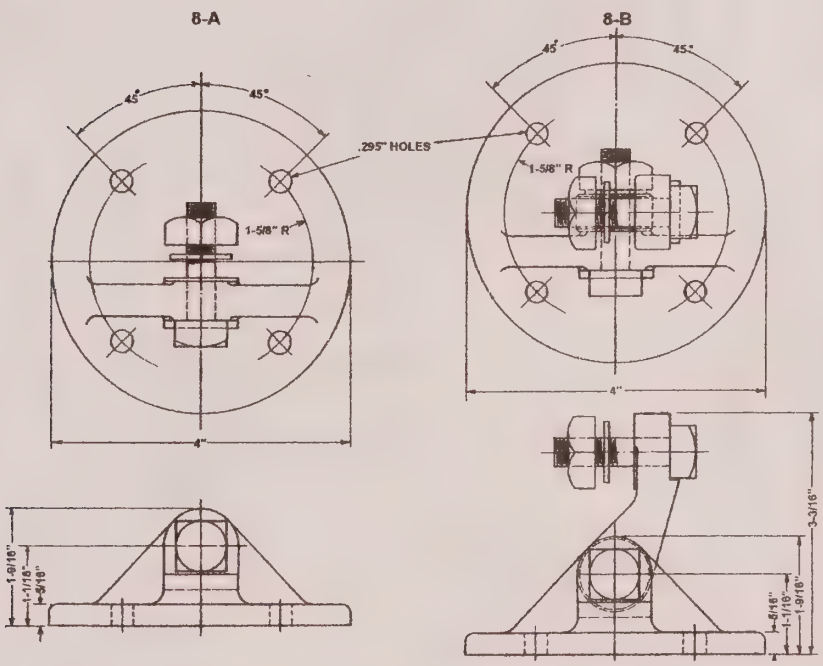
Drawing 197-B-24, 7-3-22 -
Reading stand
D-76610 assembly



Drawing 197-B-25, 7-3-22 - #196-W receiver



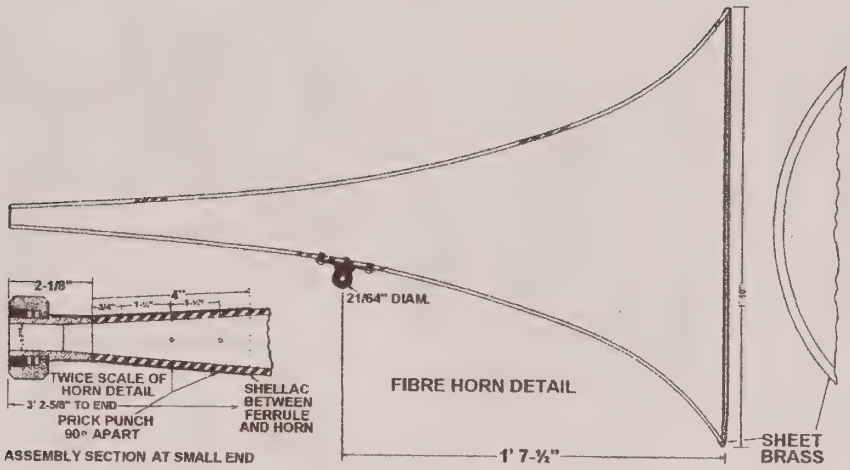
Drawing 197-B-26, 7-3-22 - Receiver housing D-76535



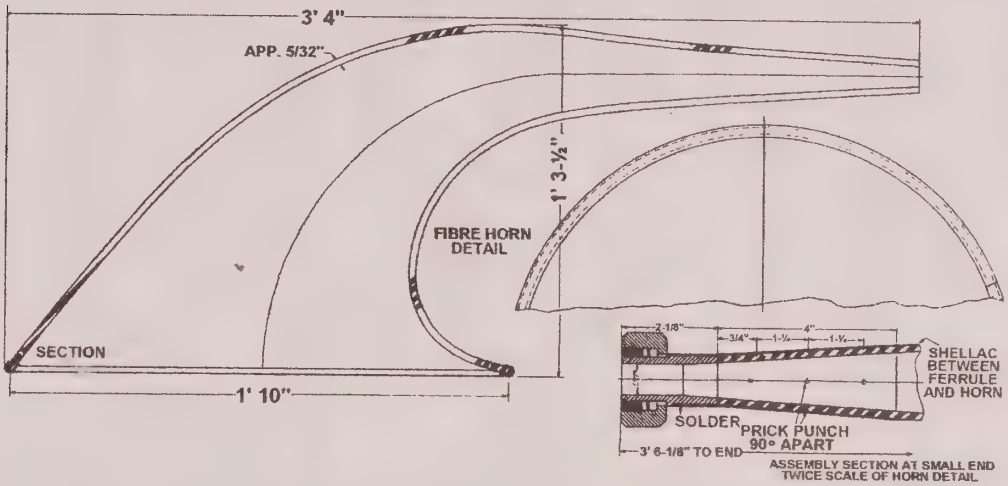
Drawing 197-B-27, 7-3-22 - 8-A and 8-B brackets

END VIEW OF LARGE END OF SECOND SECTION AND SMALL END OF FIRST SECTION
2' 5-3/4"
5/8" DRILL
1' 4½"
9/16" I. D. - 1-½" O. D. IRON WASHER. HOT DIP GALVANIZED FINISH 36 REQ.
½" X 5" IRON BOLT WITH NUT. HOT DIP GALVANIZED FINISH, 18 REQ.
10-3/4"
SEE NOTE BELOW
1/8" CLEARANCE ON ALL FOUR SIDES
¼"
3/8"
VIEW SHOWING HOW SECTIONS OVERLAP
WOOD CUT OUT FOR THROAT
2-1/16"
11-3/4"
6-5/8"
2-3/16"
VIEW SHOWING SMALL END OF HORN
TWO OF DET. 2 TO BE FURNISHED WITH EACH HORN AND ASSEMBLED AS SHOWN
DET. 2
COMMERCIAL IRON WASHER FOR 3/8" BOLT, HOT DIP GALV. FINISH
3' 4-½"
2' 7½"
2' 11/16"
END VIEW OF LARGE END OF FIRST SECTION
2' 5-3/4"
VIEW SHOWING METHOD OF JOINING CORNERS OF RIBS
HEAVY RIBS MADE FROM 2" X 4" ASH
1' 7½"
NOTE: HORNS STAMPED WITH 1" CHARACTERS 4 TIMES ON THE SAME HORN IN THE LOCATIONS GIVEN BELOW AND ON THE SURFACES INDICATED ABOVE
1 - LARGE END OF SMALL SECTION
2 - SMALL END OF MIDDLE SECTION
3 - LARGE END OF MIDDLE SECTION
4 - SMALL END OF LARGE SECTION
THIN RIBS MADE FROM 1" X 2" ASH
11-3/4"
10-3/4"
1' 7½"
VIEW SHOWING LARGE END OF THIRD SECTION AND SMALL END OF SECOND SECTION
HORN BODY - CYPRESS OR WHITE PINE 1" X 4" BOARDS TONGUE AND GROOVE JOINTS
11-½"
9-3/4"
8-½"
3' 0"
3' 6"
10' 0"
2-½"
1-½"
3/8-16 THD. U. S. STD.
DET. 2 IRON HOT DIP GALV. FINISH
2"
#196-W RECEIVER
WOOD HORN
TOP VIEW SHOWING ASSEMBLY OF RECEIVER & THROAT

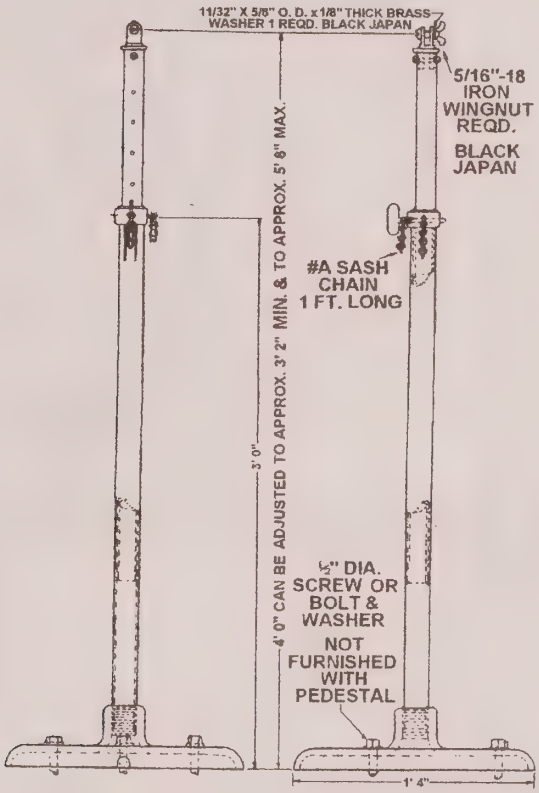
Drawing 197-B-28, 7-3-22 - #5-A horn



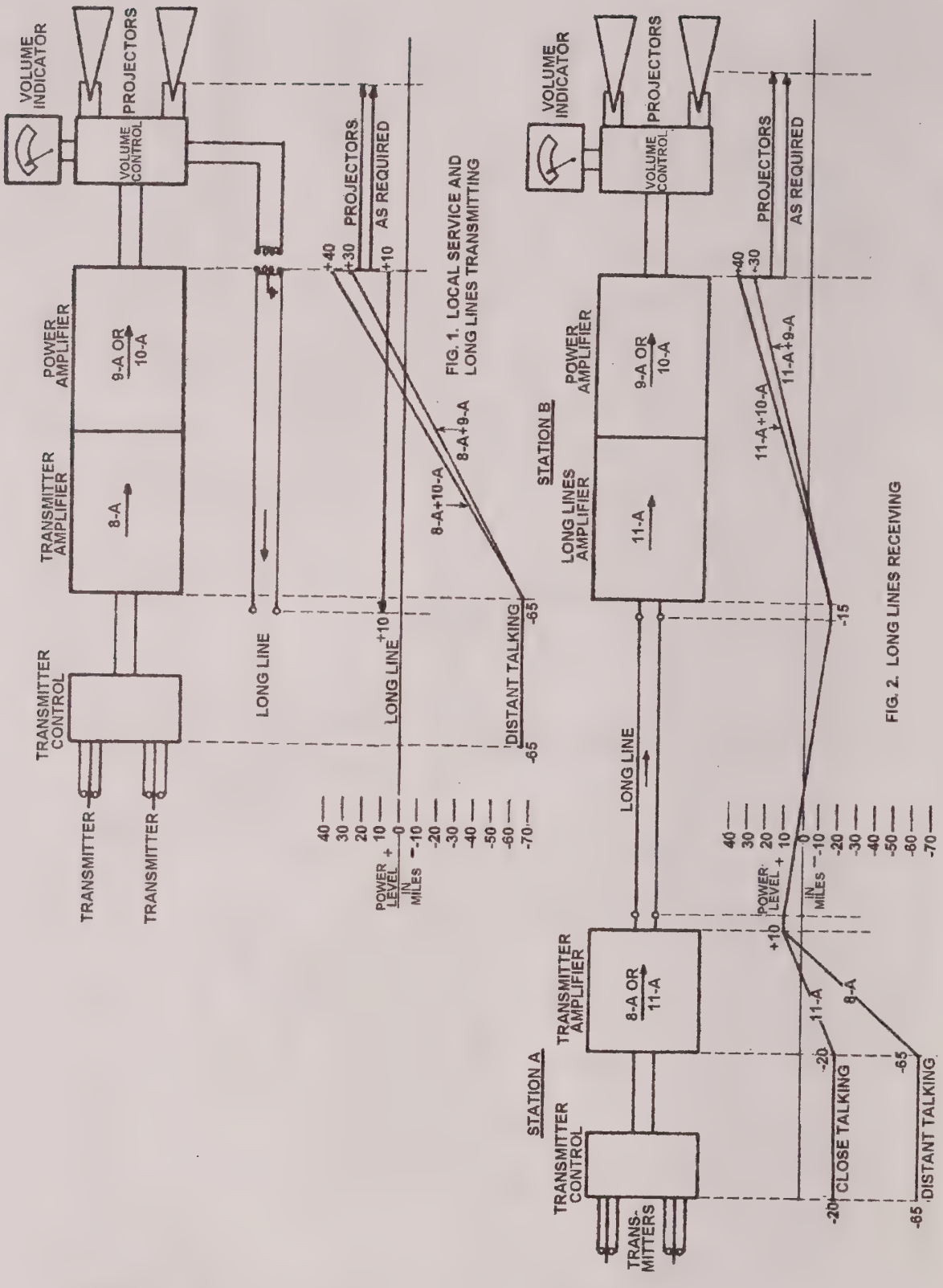
Drawing 144-A-50, 7-3-22 - #6-A horn



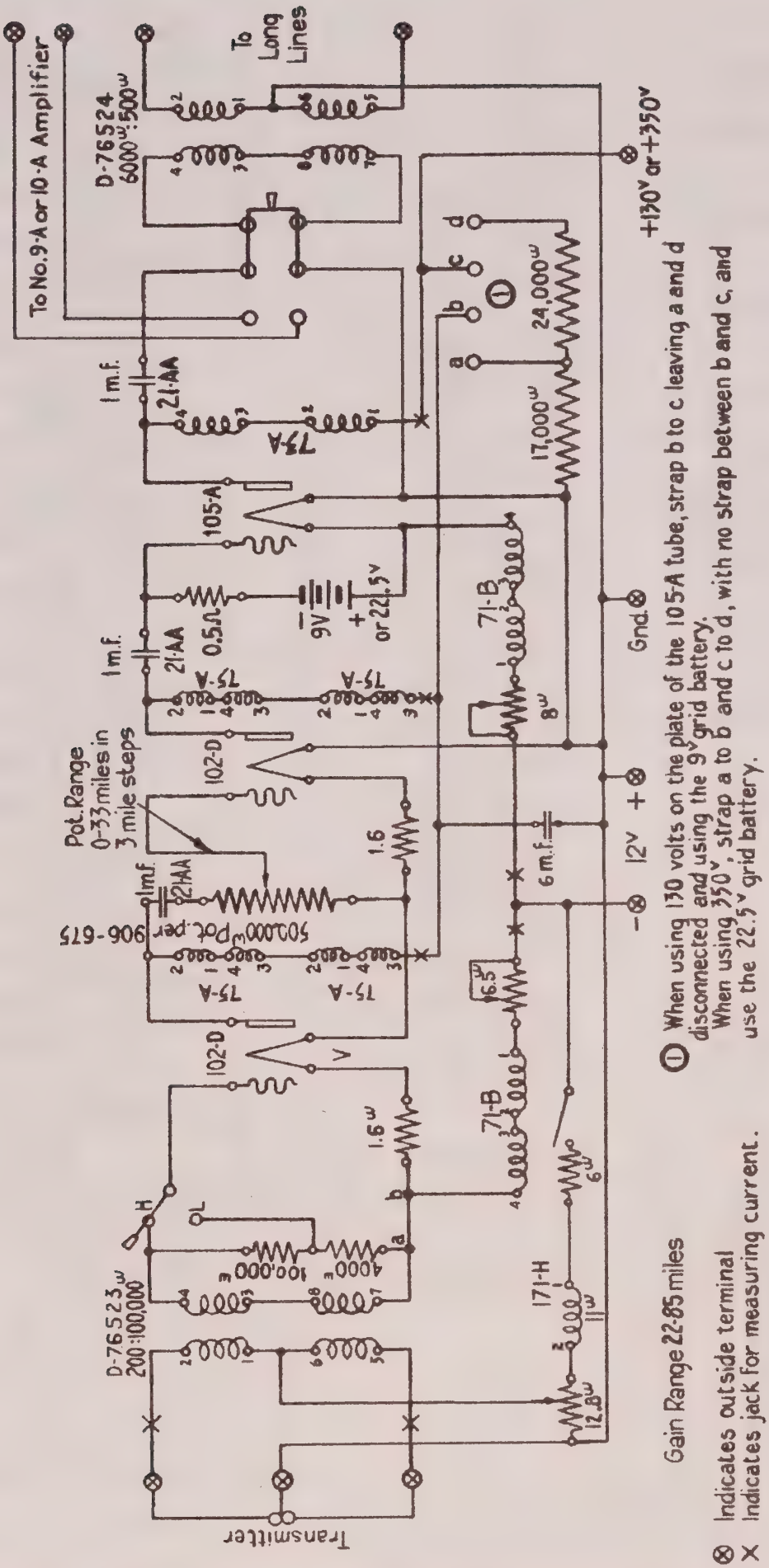
Drawing 144-A-51, 7-3-22 - #7-A horn


11/32" X 5/8" O. D. x 1/8" THICK BRASS WASHER 1 REQD. BLACK JAPAN
5/16"-18 IRON WINGNUT REQD. BLACK JAPAN
#A SASH CHAIN 1 FT. LONG
4' 0" CAN BE ADJUSTED TO APPROX. 3' 2" MIN. & TO APPROX. 5' 6" MAX.
3' 0"
½" DIA. SCREW OR BOLT & WASHER NOT FURNISHED WITH PEDESTAL
1' 4"

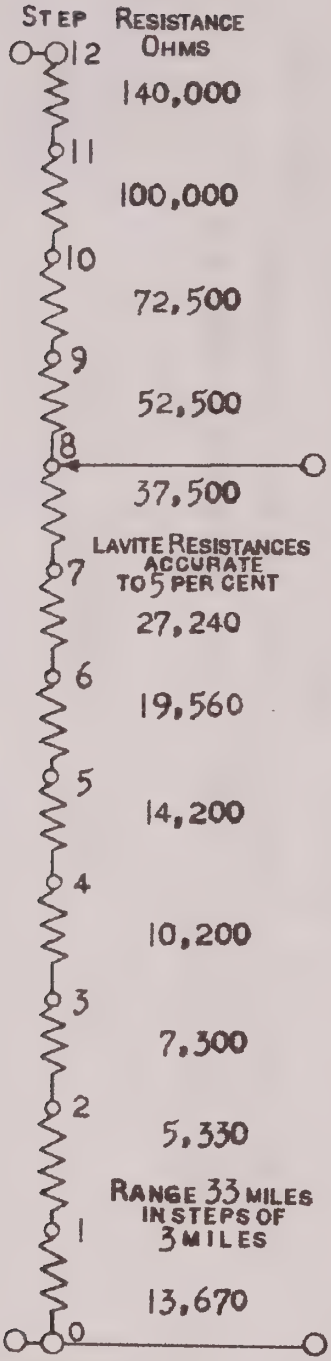
Drawing 197-B-29, 7-3-22 - Horn pedestal per D-76537 - assembly



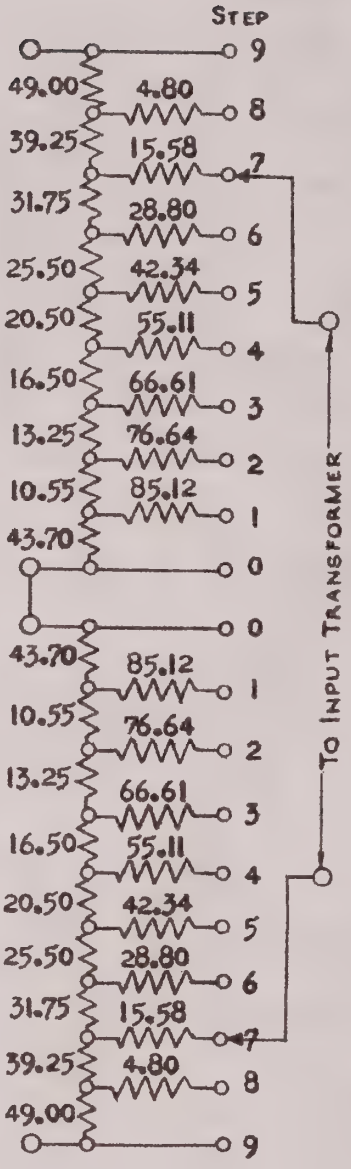
Drawing 906-867 - Schematic diagram of public address systems



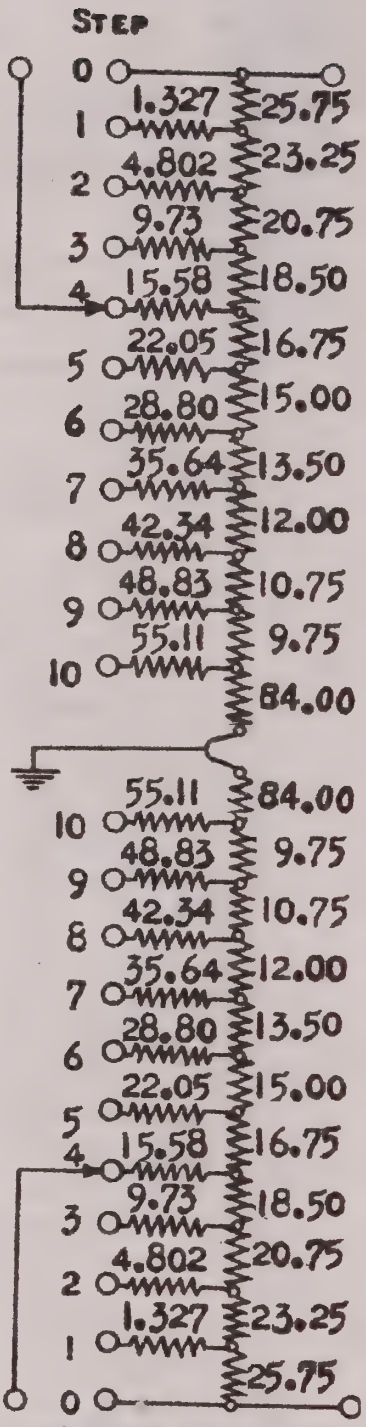
Drawing 906-[illegible]583, 12-12-21 - No. 8-A amplifier for distant talking transmitter



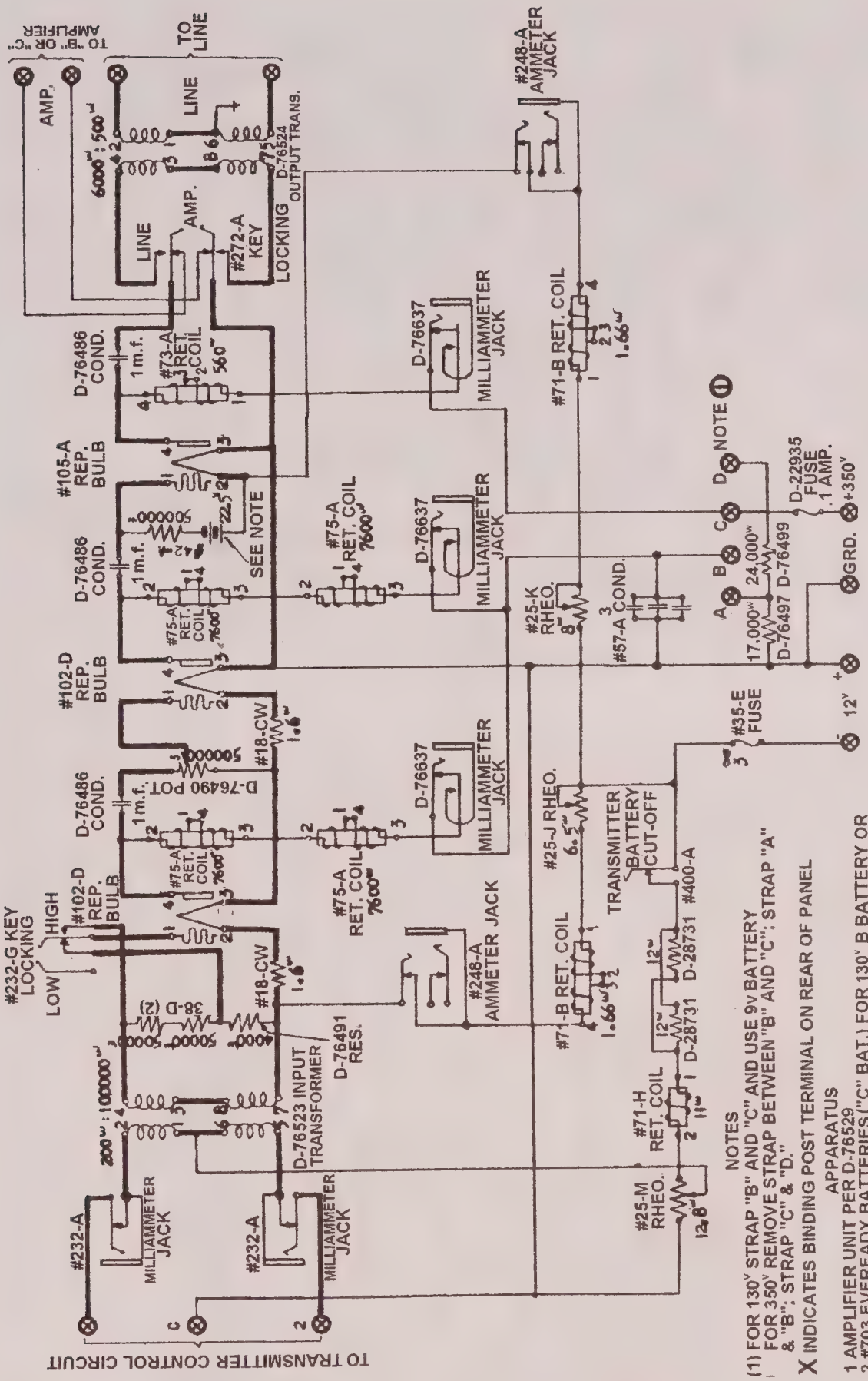
Drawing 906-675, 7-7-22 - 500,000 ohm potentiometer for amplifier no. 8-A per 906-583



Drawing 906-672, 7-7-22 - Potentiometer for amplifier no. 11-A per Dwg. No. 906-586. Range 16 miles in two-mile steps.

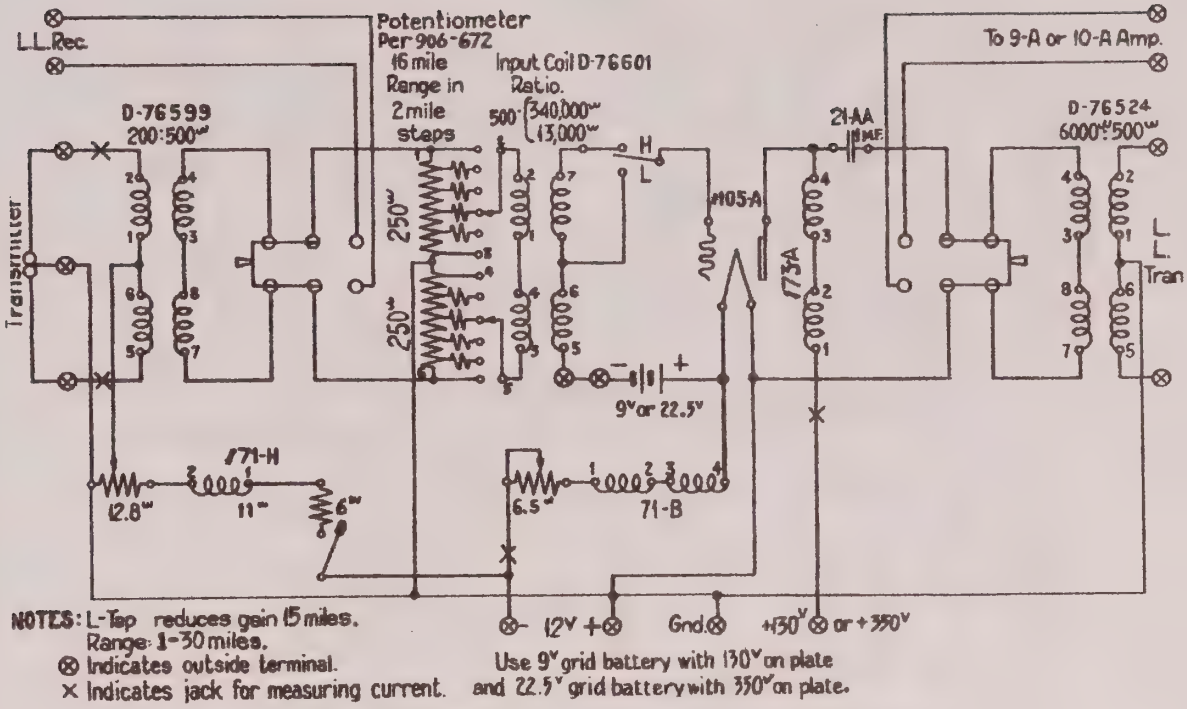


Drawing 906-674, 7-7-22 - Potentiometer for use with # 4-A gain testing circuit

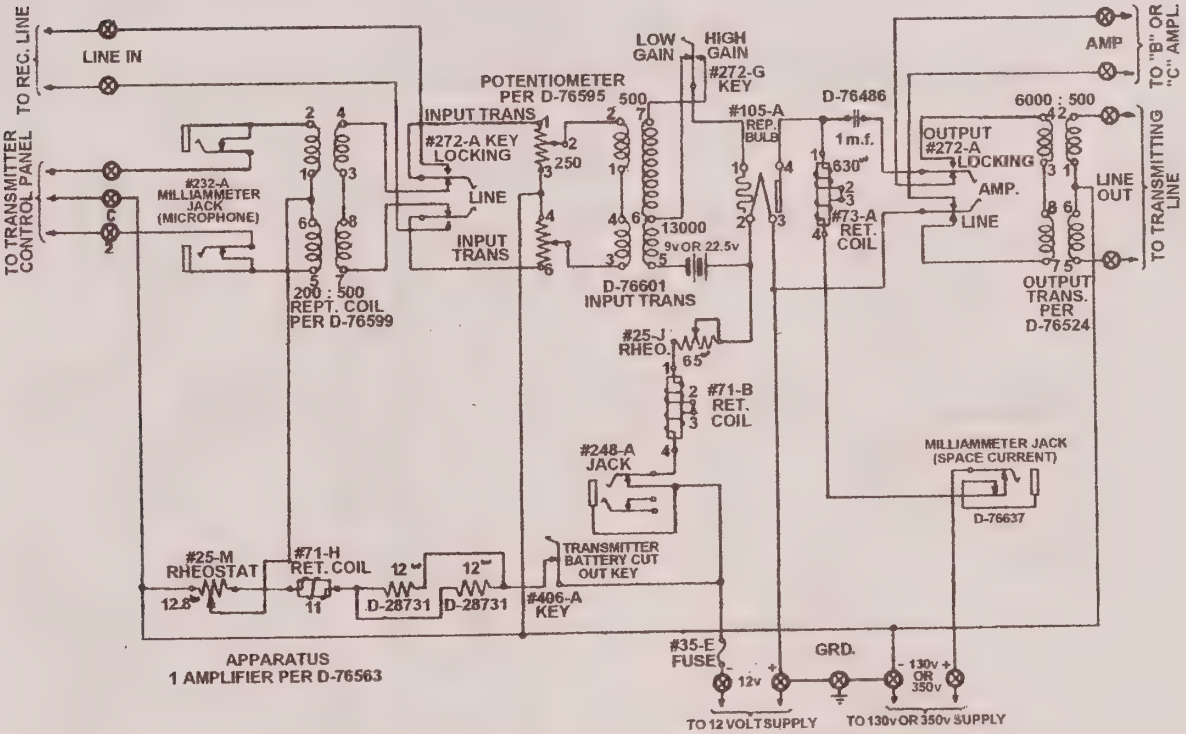


Drawing 197-B-1, 6-29-22 - Type "A" amplifier circuit

Drawing 144-A-43, 6-29-22 - "A" amplifier assembly



Drawing 906-586, 12-12-21 - No. 11-A amplifier for close-speaker transmitter or long lines receiving



Drawing 197-B-5, 6-29-22 - Type "D" amplifier

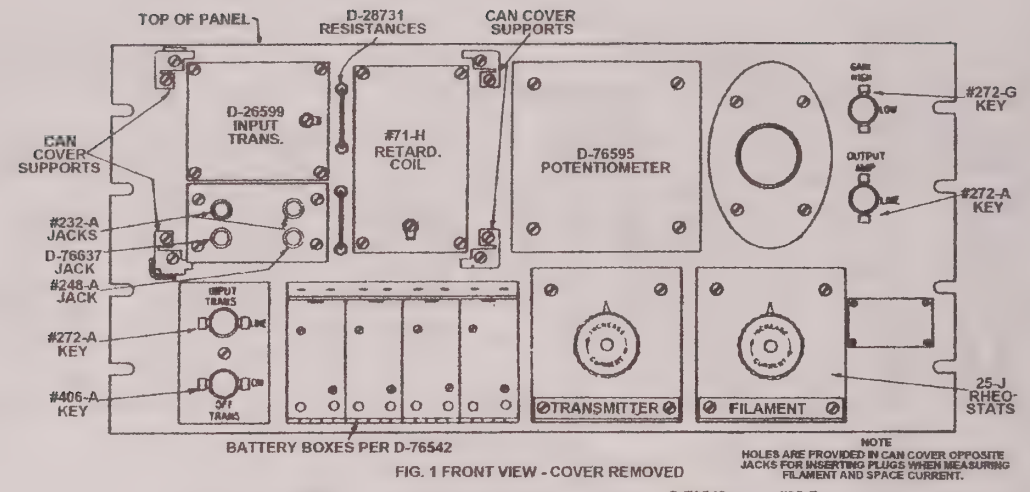


FIG. 1 FRONT VIEW - COVER REMOVED

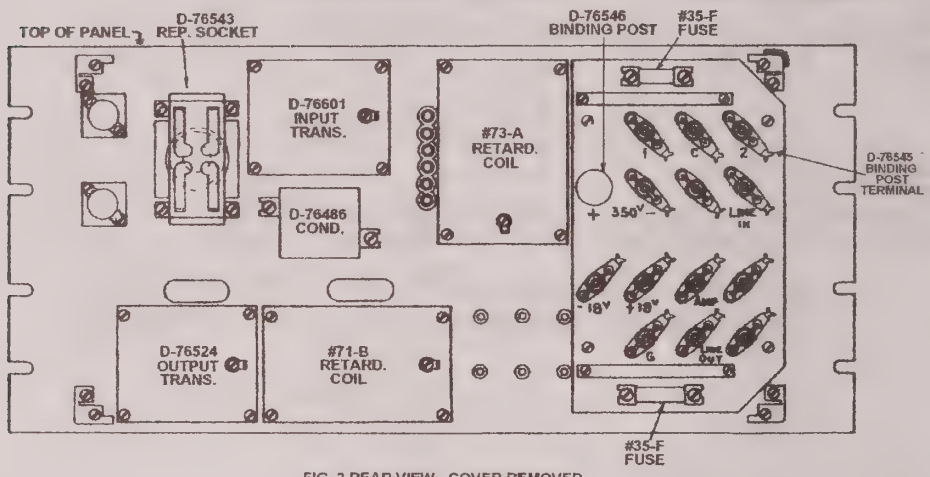
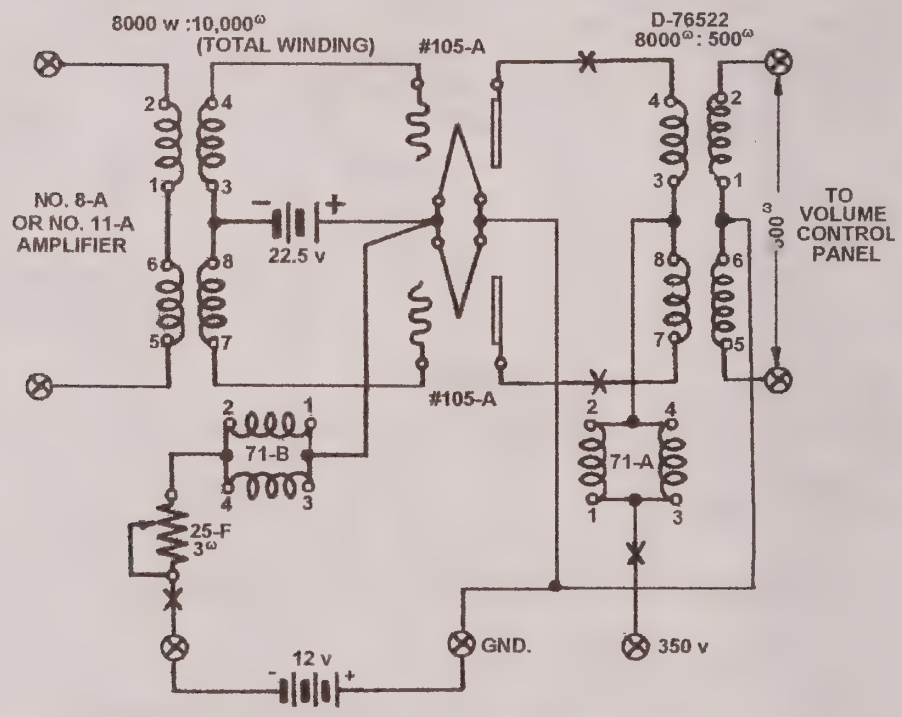


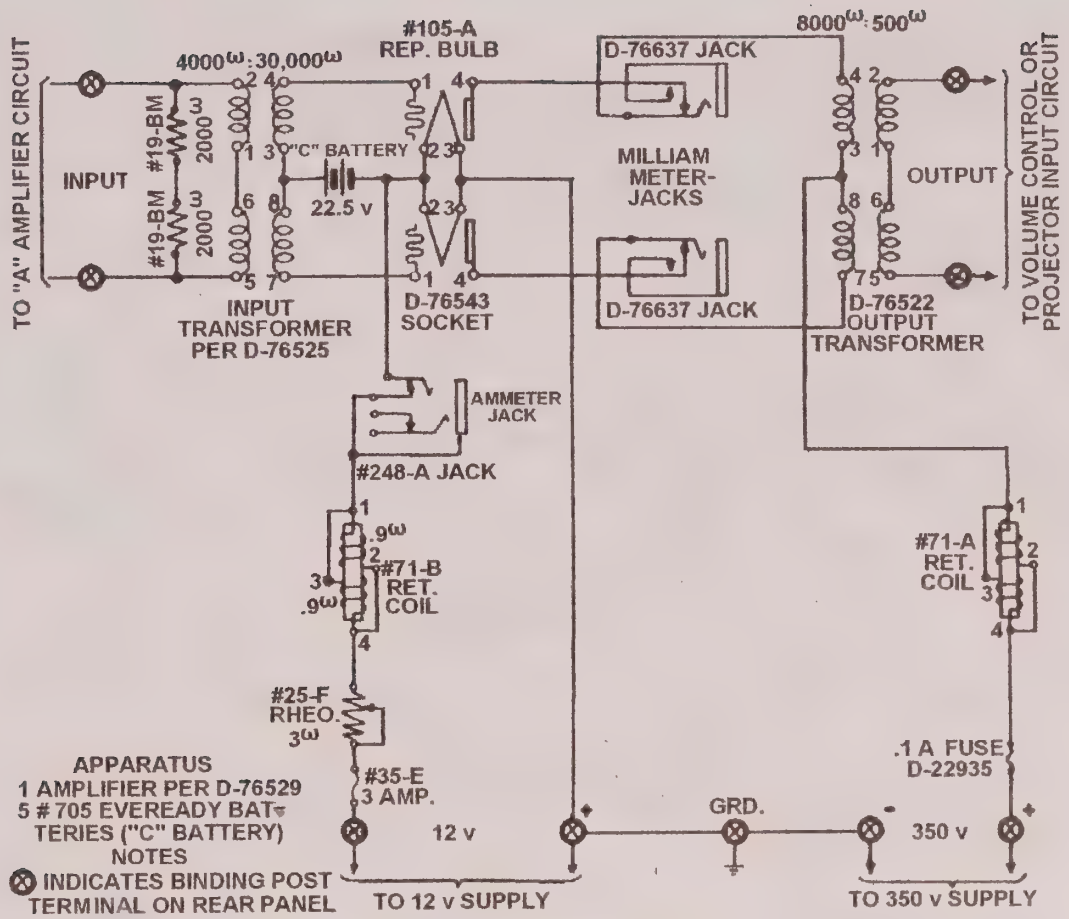
FIG. 2 REAR VIEW - COVER REMOVED

Drawing 197-B-6, 6-29-22 - Type "D" amplifier - assembly

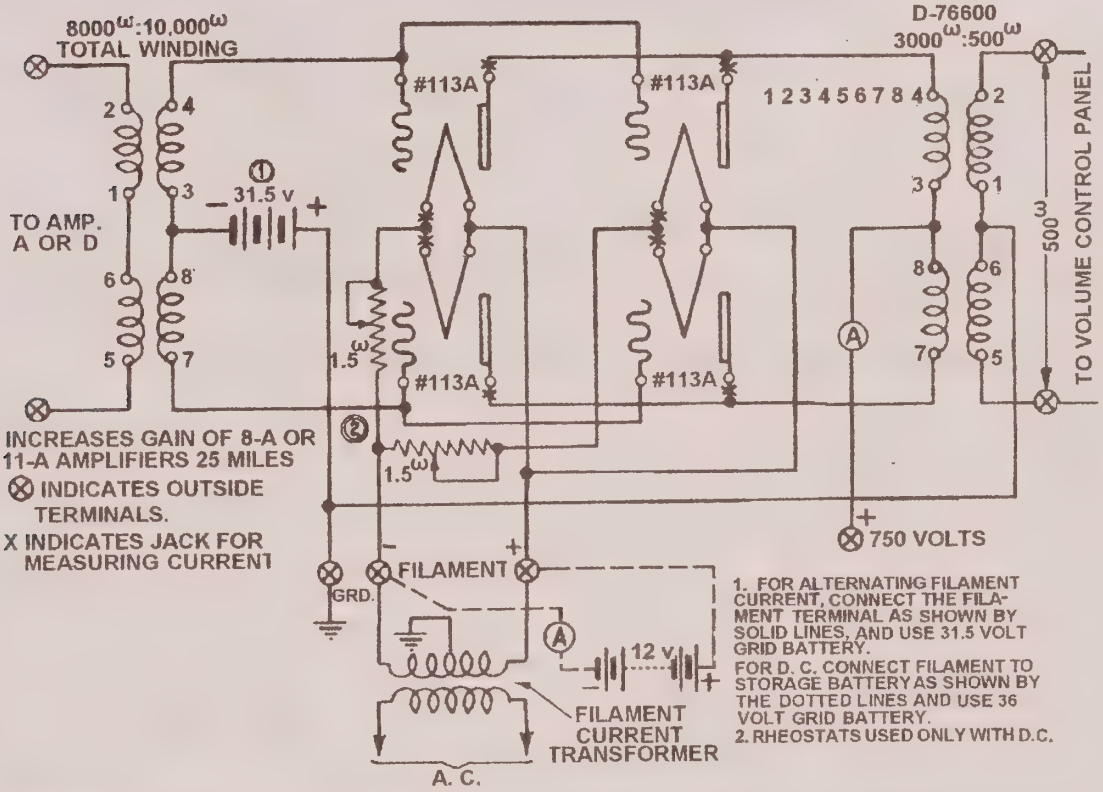


INCREASES GAIN OF NO. 8-A OR NO. 11-A AMPLIFIERS 15 MILES
⊗ INDICATES OUTSIDE TERMINAL.
X INDICATES JACK FOR MEASURING CURRENT.

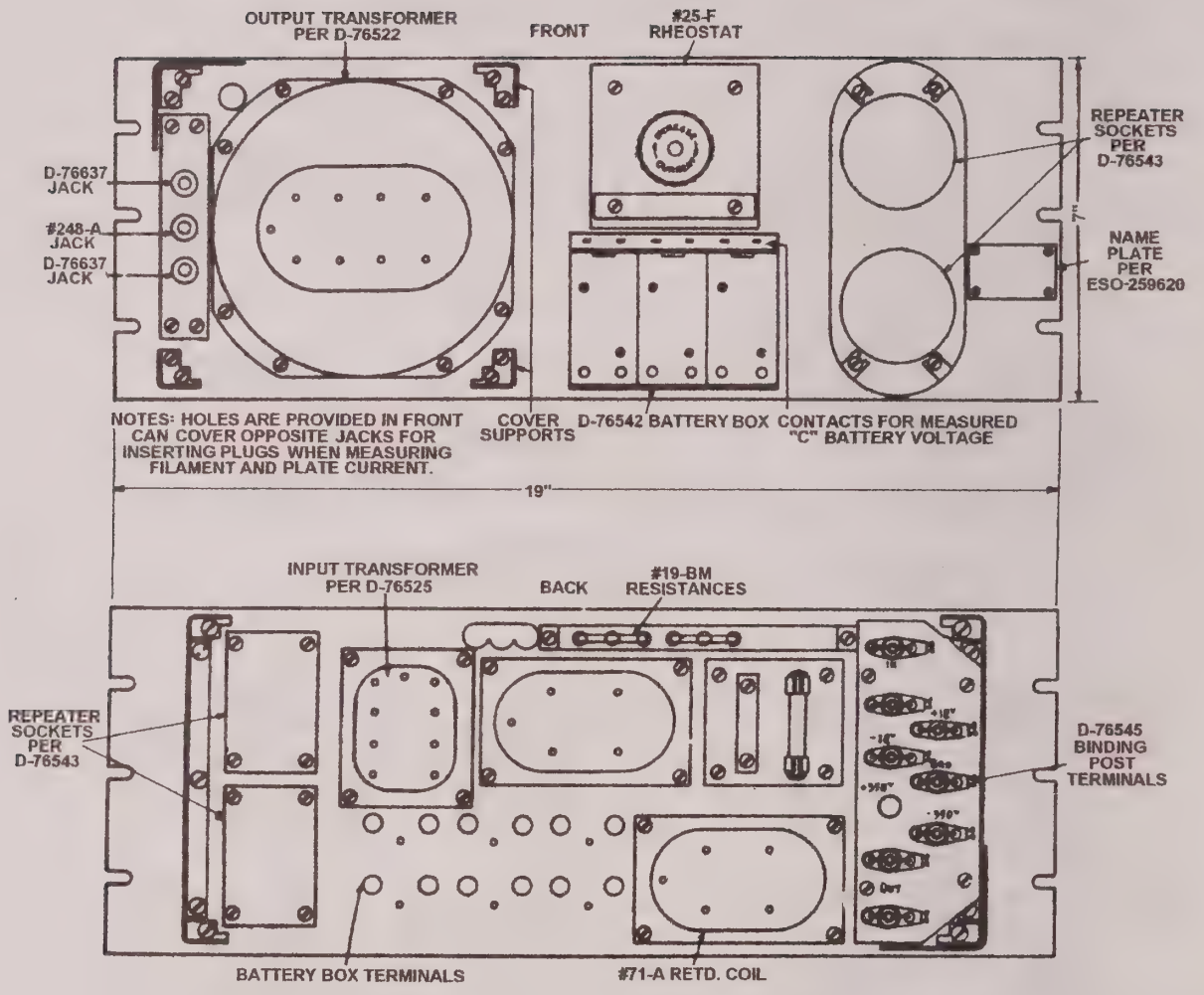
Drawing 906-584, 12-12-21 - No. 9-A amplifier - power stage for indoor service only



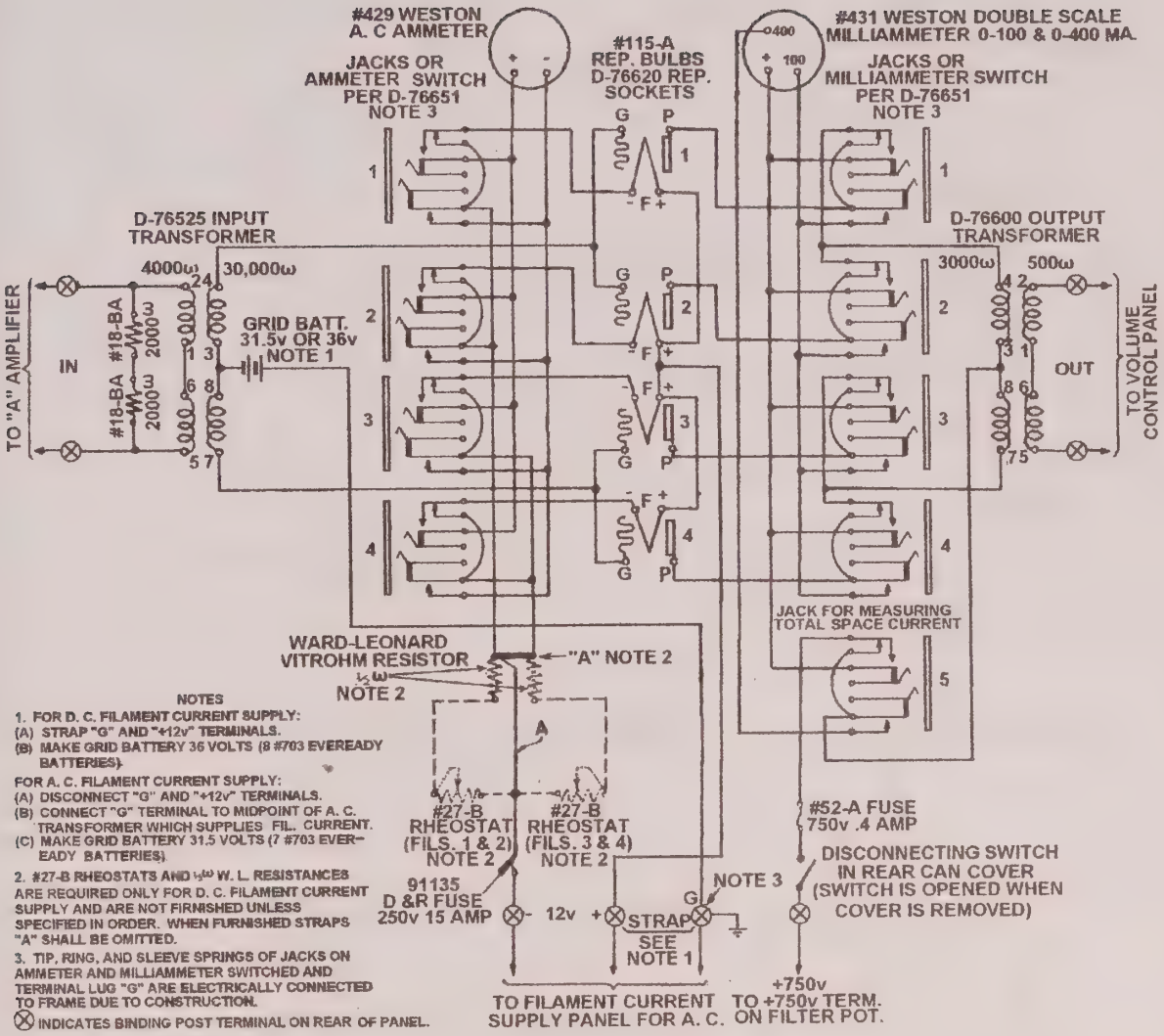
Drawing 197-B-2, 6-29-22 - Type "B" amplifier


8000ω:10,000ω TOTAL WINDING
TO AMP. A OR D
31.5 v
#113A
#113A
#113A
#113A
1.5ω
1.5ω
D-76600 3000ω:500ω
1 2 3 4 5 6 7 8 4
500ω
TO VOLUME CONTROL PANEL
INCREASES GAIN OF 8-A OR 11-A AMPLIFIERS 25 MILES
INDICATES OUTSIDE TERMINALS.
X INDICATES JACK FOR MEASURING CURRENT
GRD.
FILAMENT
750 VOLTS
12 v
FILAMENT CURRENT TRANSFORMER
A. C.
1. FOR ALTERNATING FILAMENT CURRENT, CONNECT THE FILAMENT TERMINAL AS SHOWN BY SOLID LINES, AND USE 31.5 VOLT GRID BATTERY.
FOR D. C. CONNECT FILAMENT TO STORAGE BATTERY AS SHOWN BY THE DOTTED LINES AND USE 36 VOLT GRID BATTERY.
2. RHEOSTATS USED ONLY WITH D.C.

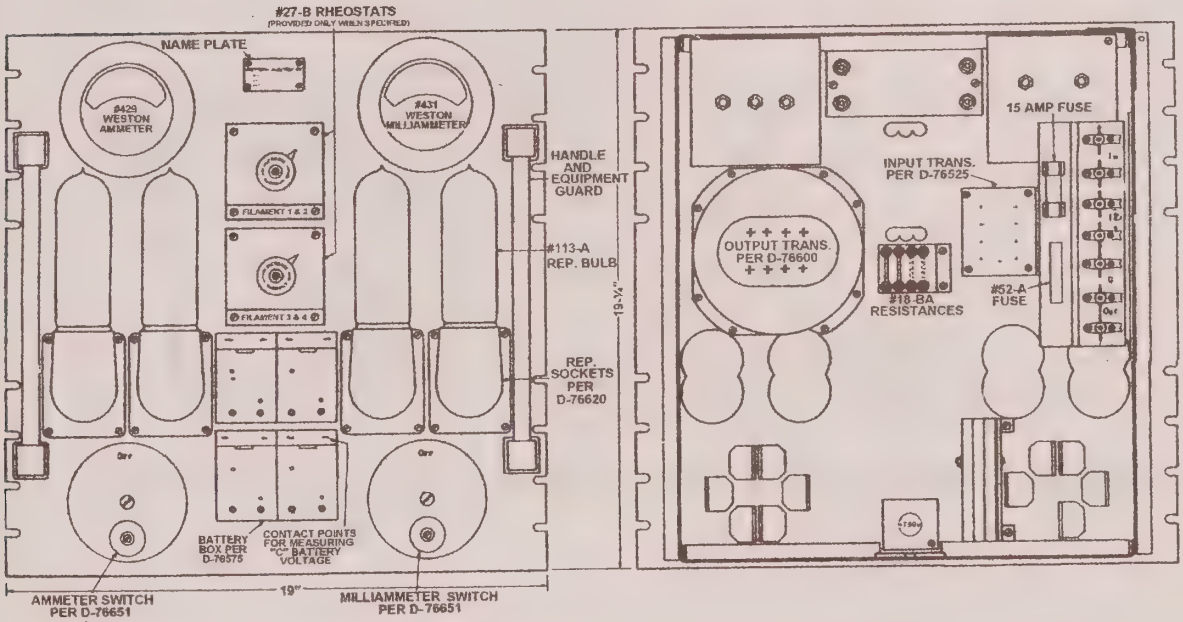
Drawing 906-585, 12-12-21 - No. 10-A amplifier - power stage for use where maximum energy is required. Arranged for either alternating or direct current in the filament.



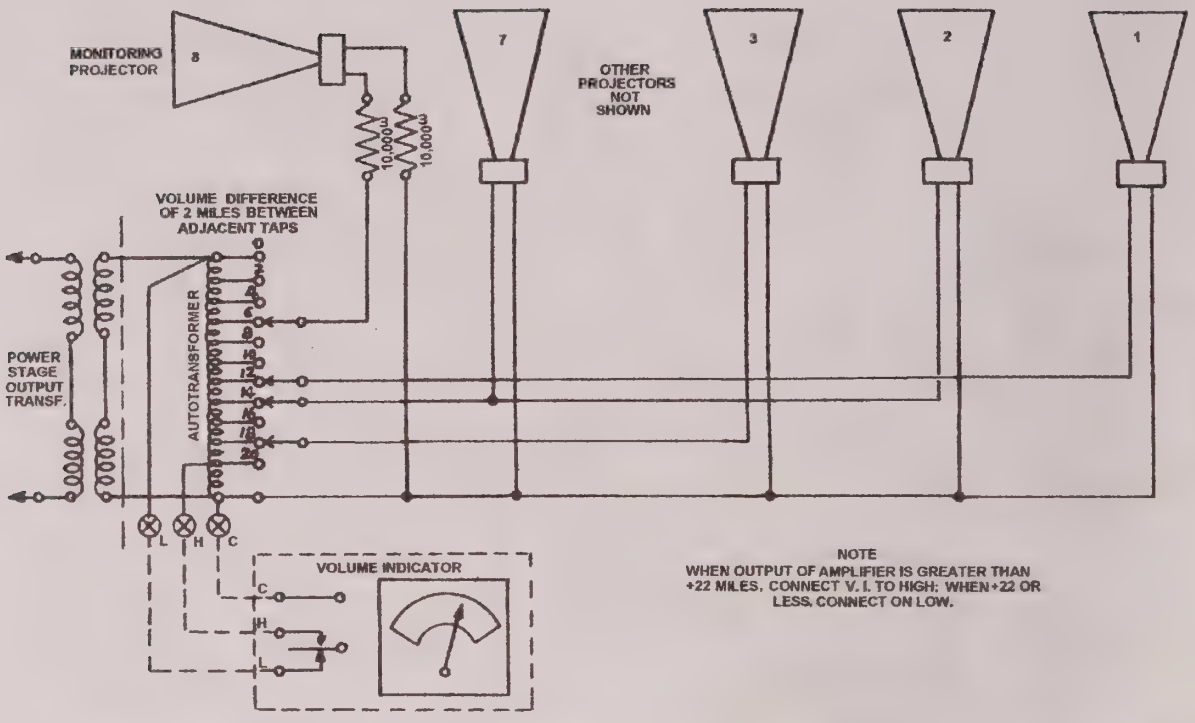
Drawing 197-B-3, 6-29-22 - Type "B" amplifier - assembly


#429 WESTON A. C AMMETER
JACKS OR AMMETER SWITCH PER D-76651 NOTE 3
#115-A REP. BULBS D-76620 REP. SOCKETS
#431 WESTON DOUBLE SCALE MILLIAMMETER 0-100 & 0-400 MA.
JACKS OR MILLIAMMETER SWITCH PER D-76651 NOTE 3
D-76525 INPUT TRANSFORMER
4000ω
30,000ω
D-76600 OUTPUT TRANSFORMER
3000ω
500ω
TO "A" AMPLIFIER
IN
#18-BA 2000ω
#18-BA 2000ω
GRID BATT. 31.5v OR 36v NOTE 1
OUT
TO VOLUME CONTROL PANEL
JACK FOR MEASURING TOTAL SPACE CURRENT
WARD-LEONARD VITROHM RESISTOR ½ω NOTE 2
"A" NOTE 2
NOTES
1. FOR D. C. FILAMENT CURRENT SUPPLY:
(A) STRAP "G" AND "+12v" TERMINALS.
(B) MAKE GRID BATTERY 36 VOLTS (8 #703 EVEREADY BATTERIES).
FOR A. C. FILAMENT CURRENT SUPPLY:
(A) DISCONNECT "G" AND "+12v" TERMINALS.
(B) CONNECT "G" TERMINAL TO MIDPOINT OF A. C. TRANSFORMER WHICH SUPPLIES FIL. CURRENT.
(C) MAKE GRID BATTERY 31.5 VOLTS (7 #703 EVEREADY BATTERIES).
2. #27-B RHEOSTATS AND ½ω W. L. RESISTANCES ARE REQUIRED ONLY FOR D. C. FILAMENT CURRENT SUPPLY AND ARE NOT FIRNISHED UNLESS SPECIFIED IN ORDER. WHEN FURNISHED STRAPS "A" SHALL BE OMITTED.
3. TIP, RING, AND SLEEVE SPRINGS OF JACKS ON AMMETER AND MILLIAMMETER SWITCHED AND TERMINAL LUG "G" ARE ELECTRICALLY CONNECTED TO FRAME DUE TO CONSTRUCTION.
⊗ INDICATES BINDING POST TERMINAL ON REAR OF PANEL.
#27-B RHEOSTAT (FILS. 1 & 2) NOTE 2
#27-B RHEOSTAT (FILS. 3 & 4) NOTE 2
#52-A FUSE 750v .4 AMP
DISCONNECTING SWITCH IN REAR CAN COVER (SWITCH IS OPENED WHEN COVER IS REMOVED)
91135 D &R FUSE 250v 15 AMP
12v
NOTE 3
STRAP SEE NOTE 1
TO FILAMENT CURRENT SUPPLY PANEL FOR A. C.
+750v TO +750v TERM. ON FILTER POT.

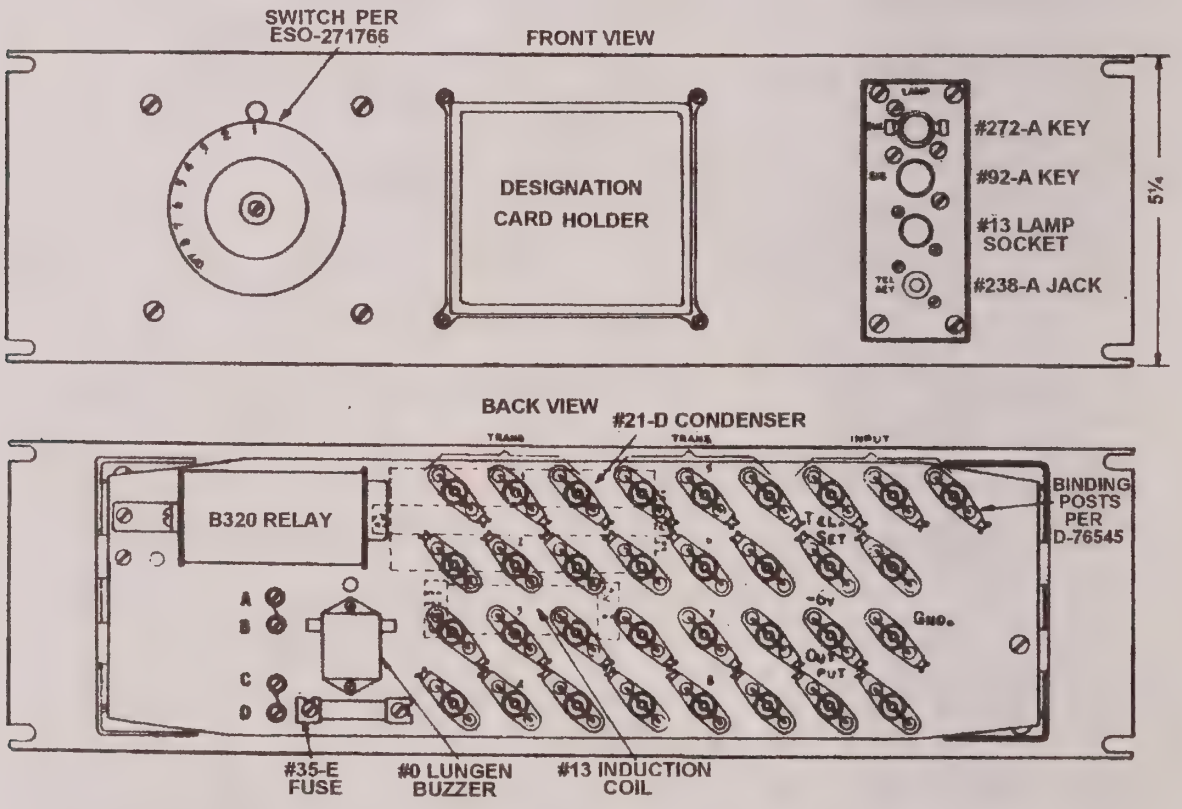
Drawing 197-B-4, 6-29-22 - Type "C" amplifier



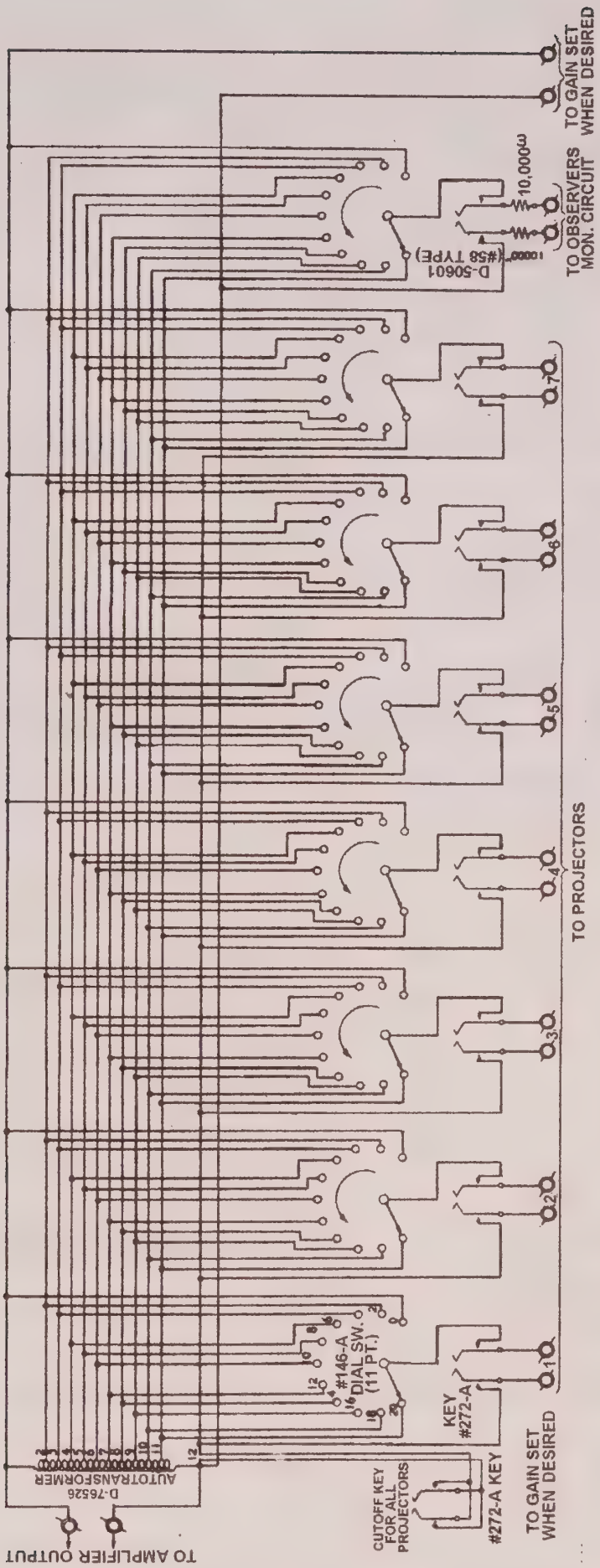
Drawing 144-A-43, 6-29-22 - Type C amplifier per D-76562 - assembly



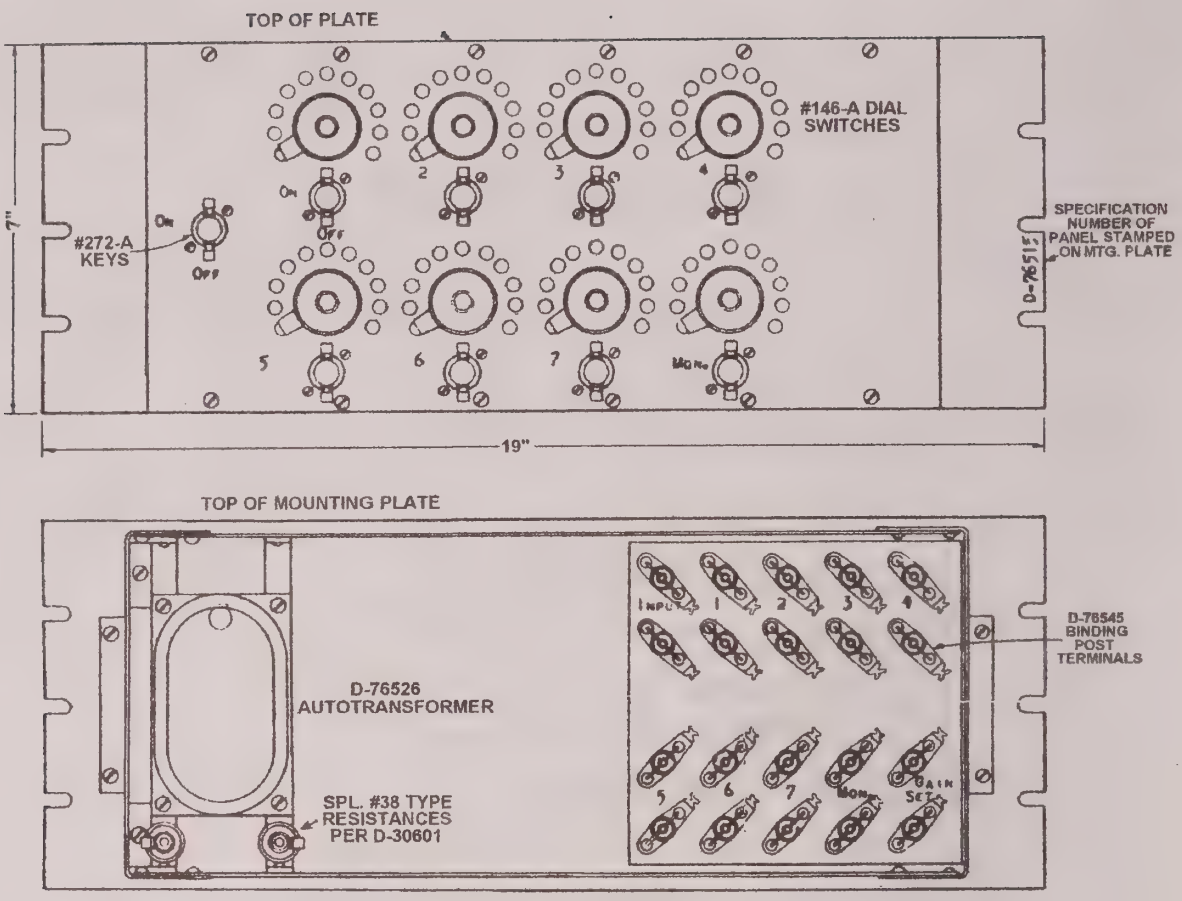
Drawing 906-862, 7-7-22 - Schematic diagram of volume control circuit



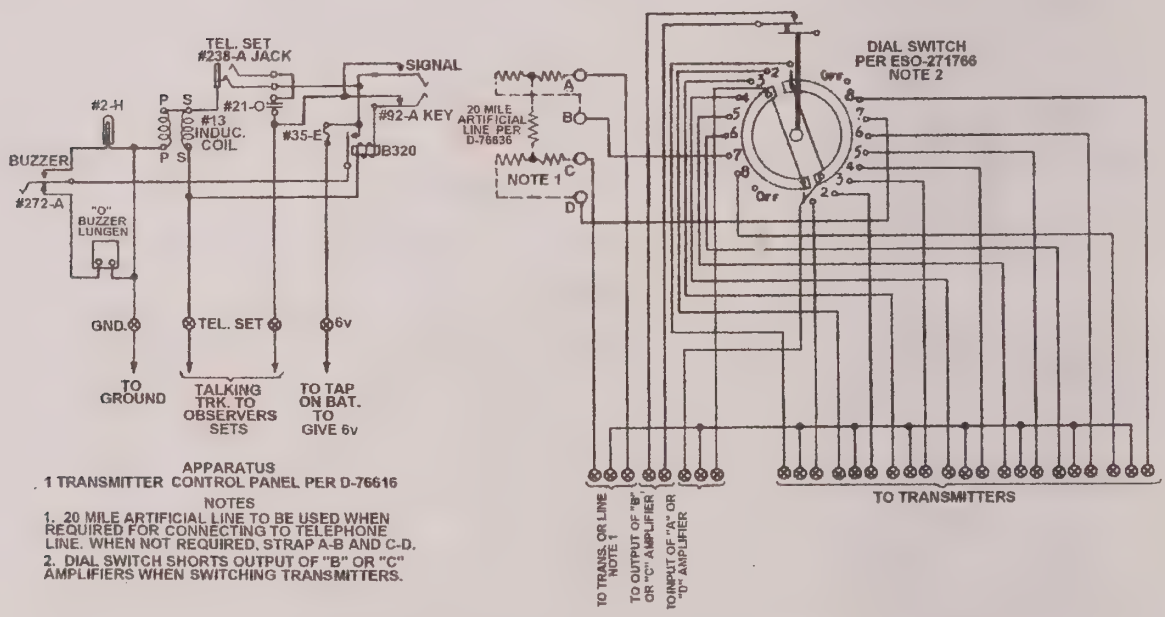
Drawing 197-B-8, 6-29-22 - D-76616 transmitter control panel - assembly



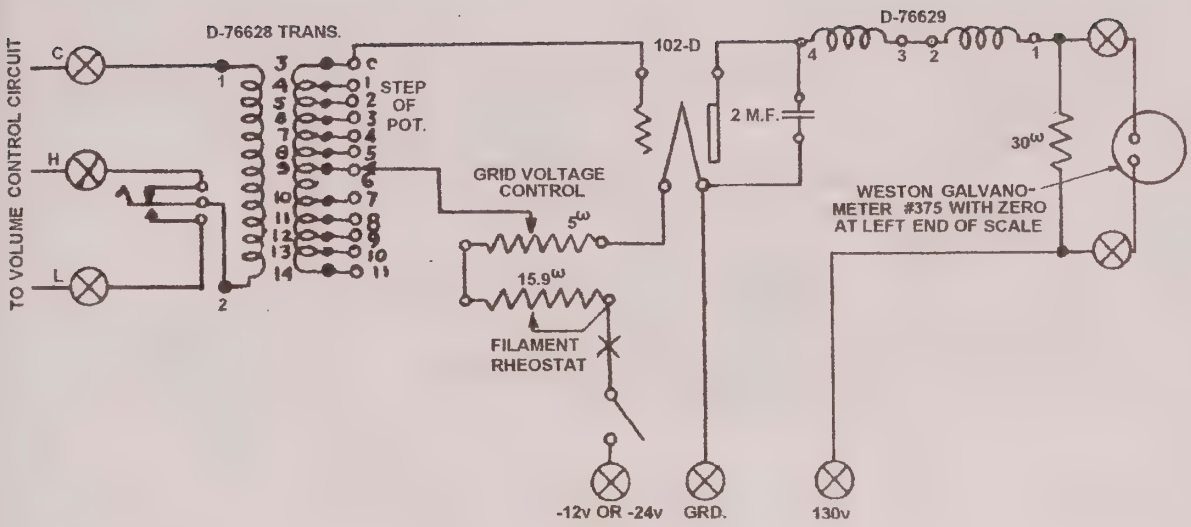
Drawing 144-A-44, 6-29-22 - Volume-control circuit



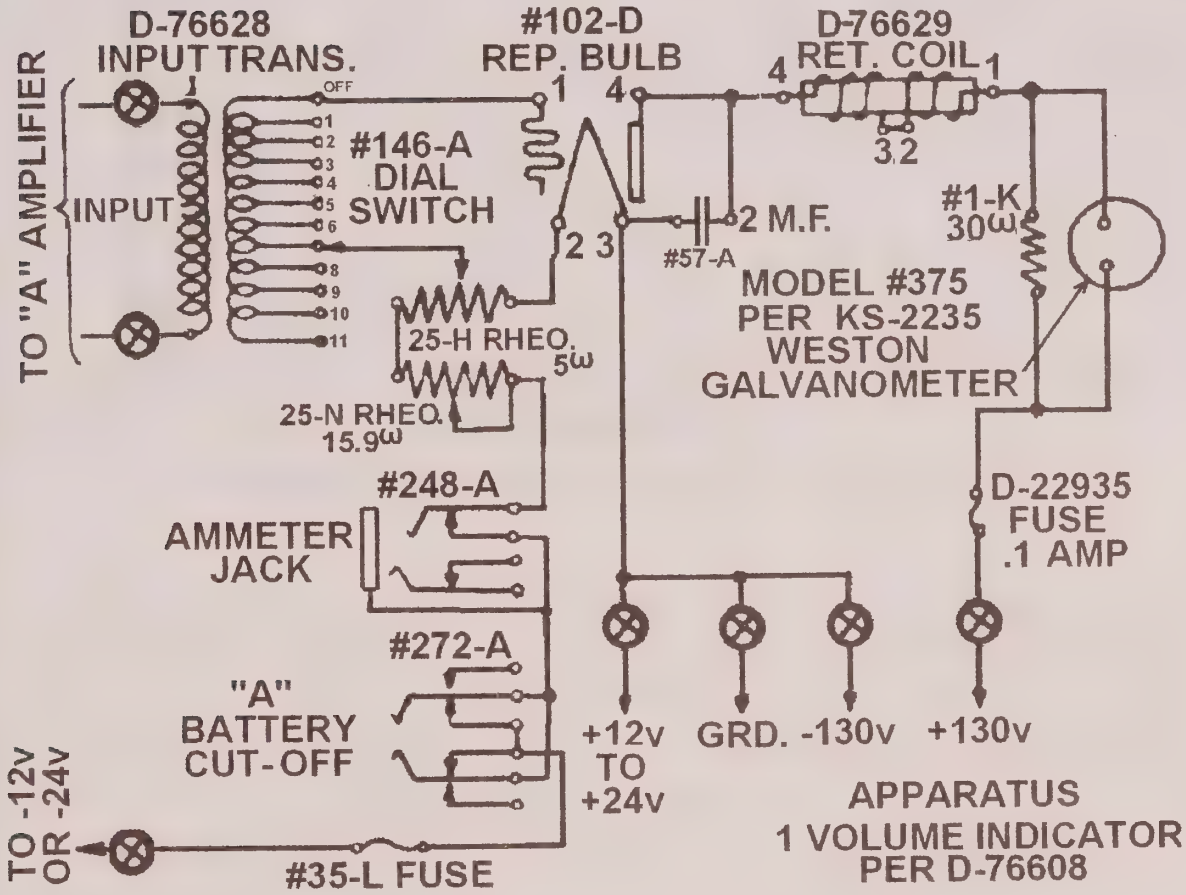
Drawing 197-B-9, 6-29-22 - Volume-control panel - assembly


TEL. SET #238-A JACK
SIGNAL
#2-H
#21-O
#13 INDUC. COIL
#35-E
#92-A KEY
B320
BUZZER
#272-A
"O" BUZZER LUNGEN
20 MILE ARTIFICIAL LINE PER D-76636
NOTE 1
DIAL SWITCH PER ESO-271766 NOTE 2
GND.
TEL. SET
6v
TO GROUND
TALKING TRK. TO OBSERVERS SETS
TO TAP ON BAT. TO GIVE 6v
TO TRANSMITTERS
TO TRANS. OR LINE NOTE 1
TO OUTPUT OF "B" OR "C" AMPLIFIER
TO INPUT OF "A" OR "D" AMPLIFIER
APPARATUS
1 TRANSMITTER CONTROL PANEL PER D-76616
NOTES
1. 20 MILE ARTIFICIAL LINE TO BE USED WHEN REQUIRED FOR CONNECTING TO TELEPHONE LINE. WHEN NOT REQUIRED, STRAP A-B AND C-D.
2. DIAL SWITCH SHORTS OUTPUT OF "B" OR "C" AMPLIFIERS WHEN SWITCHING TRANSMITTERS.

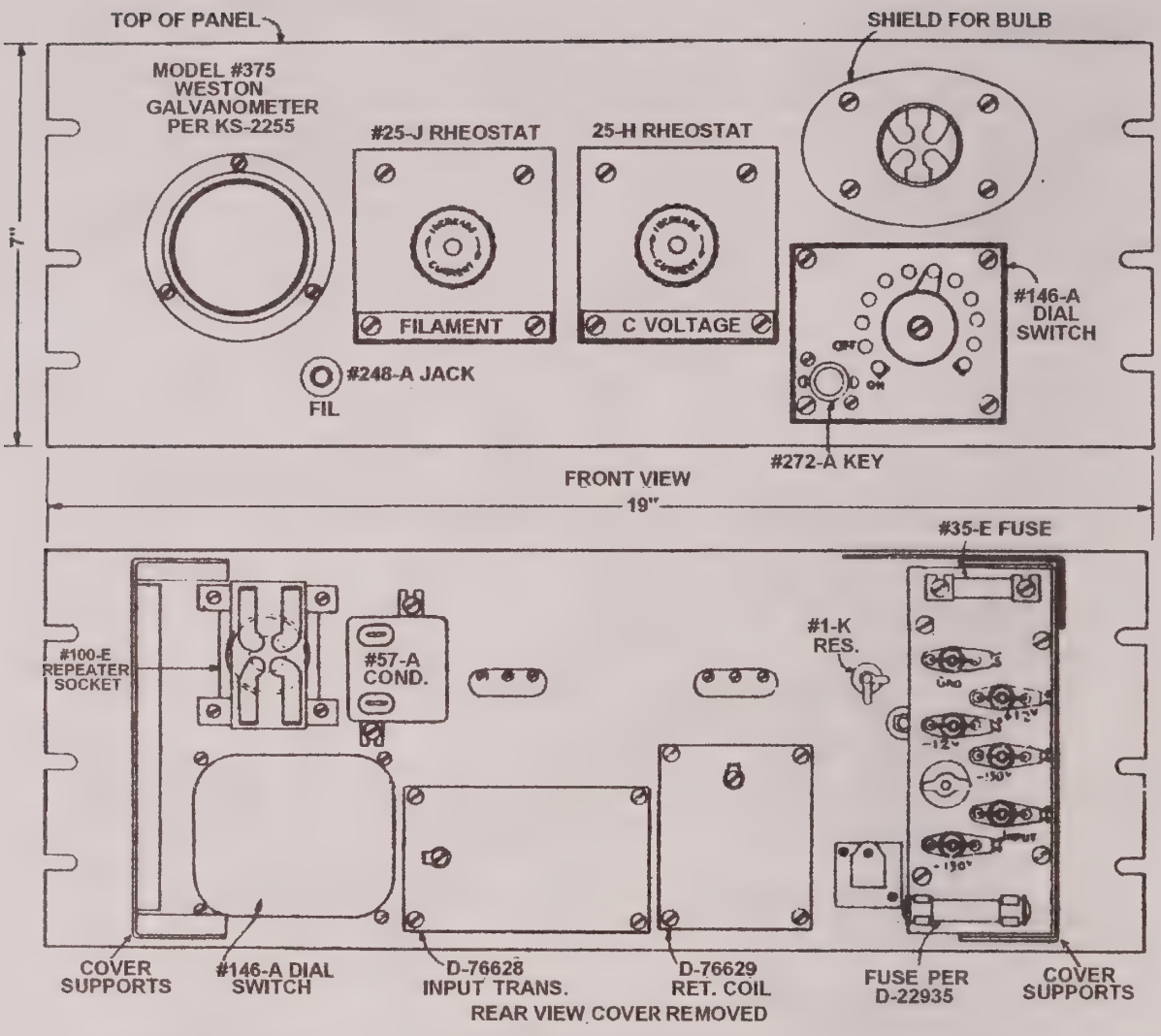
Drawing 197-B-7, 6-29-22 - Transmitter control circuit



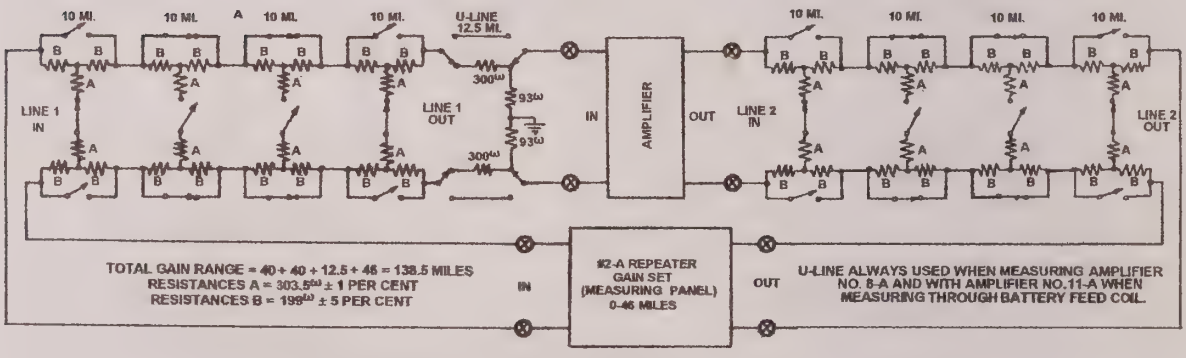
Drawing 906-673, 7-7-22 - Volume indicator



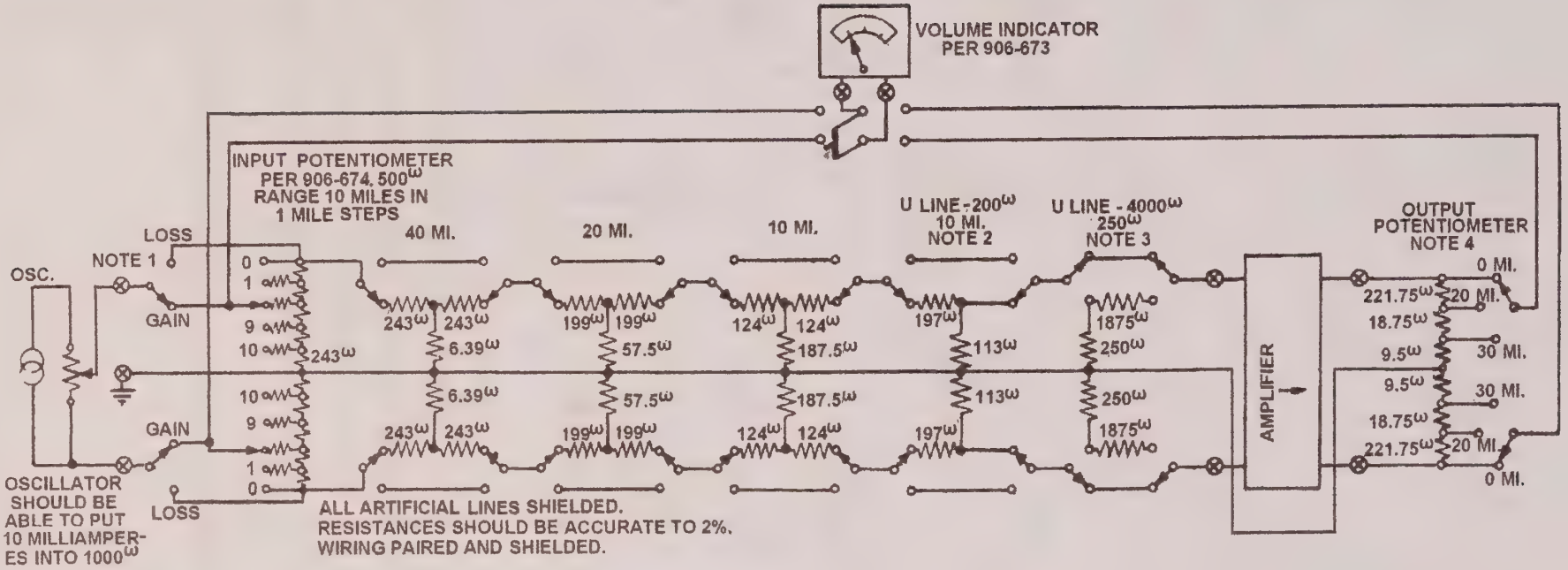
Drawing 197-B-10, 6-29-22 - Volume indicator



Drawing 197-B-11, 6-29-22 - Volume indicator - assembly



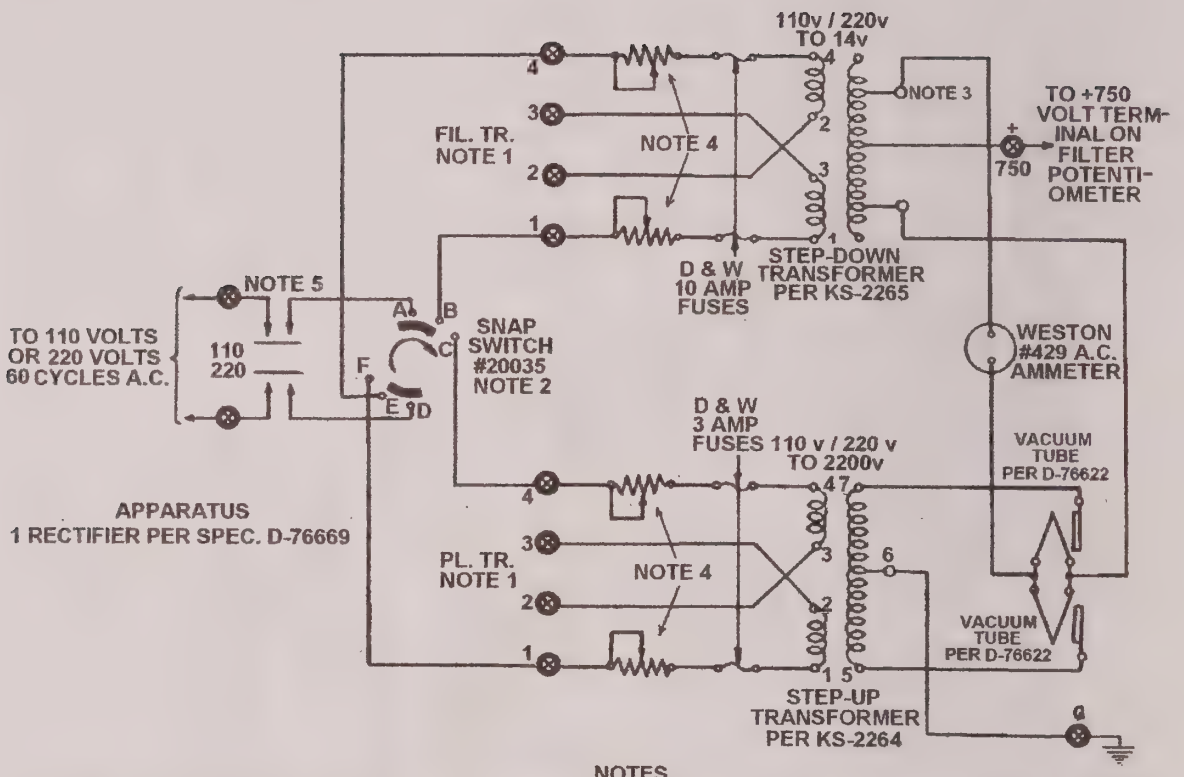
Drawing 906-852, 6-29-22 - Gain-testing circuit using
#2-A repeater gain set and 800-ohm articficial line



NOTES

1. TO MEASURE GAIN THROW SWITCH TO "GAIN" AND READ SUM OF ARTIFICIAL LINE AND BOTH POT. SETTINGS. TO MEASURE LOSS, THROW SW. TO "LOSS", CUT OUT ART. LINE, AND READ POT. SETTINGS.
2. ALWAYS USED WHEN MEASURING AMPLIFIER A AND WITH AMPLIFIER D WHEN MEASURING THROUGH BATTERY FEED COIL.
3. USED ONLY WHEN TESTING AMPLIFIER B OR C ALONE.
4. FOR AMPLIFIERS NOS. 8-A, 9-A, 10-A, OR 11-A ALONE. FOR AMPLIFIERS NOS. 8-A OR NO. 11+ NO. 9-A SET AT 20 MI., IF MEASURING GAIN OF 20 MILES OR OVER. FOR AMPLIFIERS NO. 8-A OR 11-A + NO. 10-A SET AT 30 MI., IF MEASURING GAIN OF 30 MILES OR OVER. THESE RESISTANCES MUST BE ABLE TO DISSIPATE 25 WATTS CONTINUOUSLY WITHOUT OVERHEATING.

Drawing 906-851, 6-30-22 - Schematic diagram of gain-testing circuit

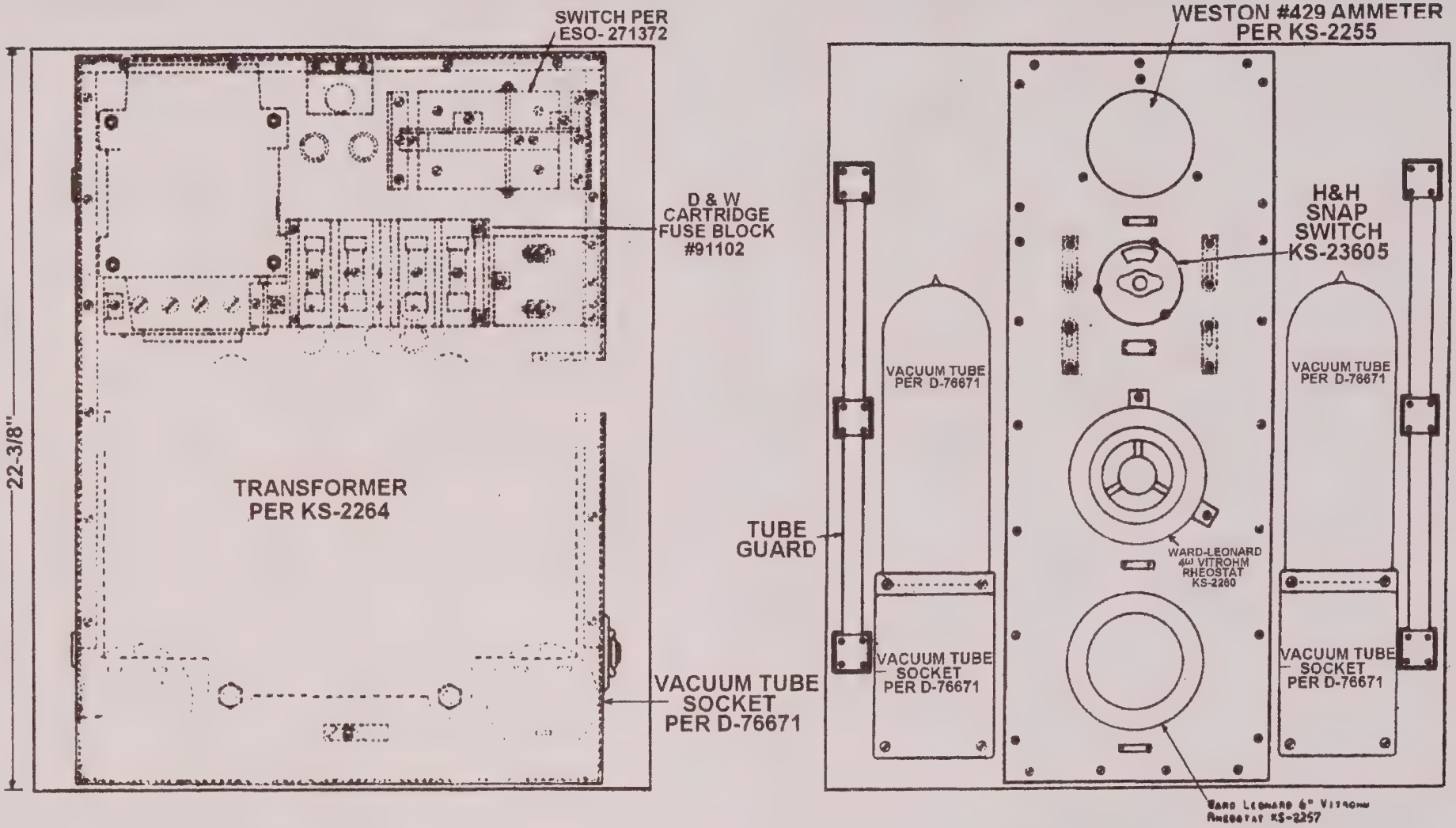


NOTES

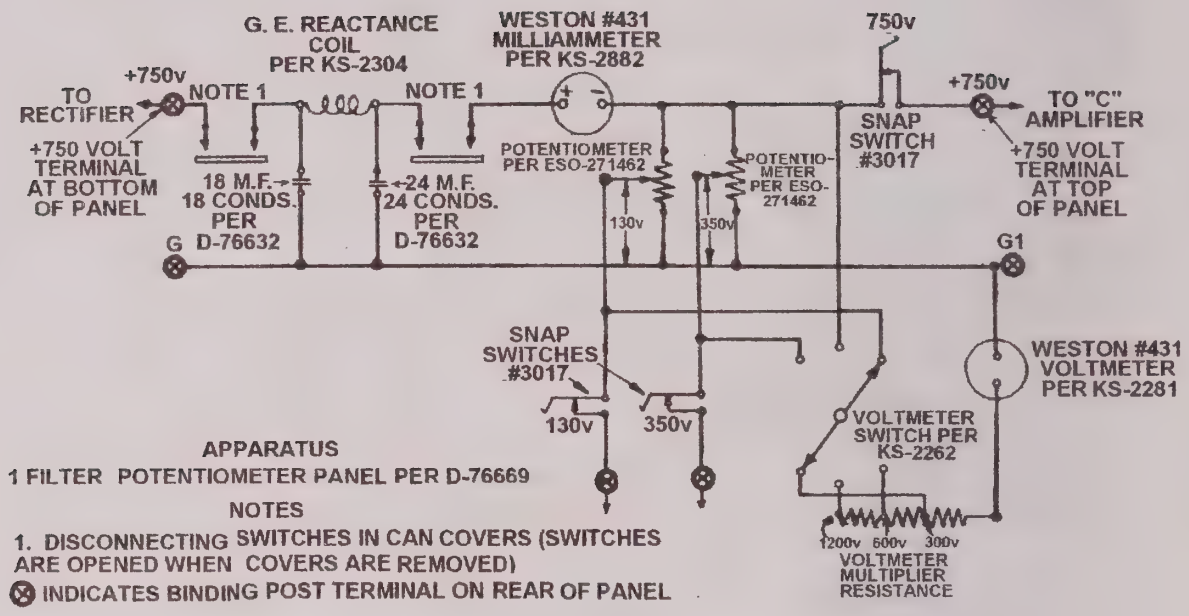
1. FOR 110 VOLT A.C. SUPPLY. STRAP TERMINALS 1 AND 2. AND 3 AND 4. TO CONNECT PRIMARY WINDINGS IN PARALLEL. FOR 220 VOLT A.C. SUPPLY STRAP TERMINALS 2 AND 3 ONLY TO CONNECT PRIMARY WINDINGS IN SERIES.
2. SNAP SWITCH IS SHOWN IN OFF POSITION. SECOND POSITION OF SWITCH CLOSES CIRCUIT THROUGH STEP-DOWN TRANSFORMER AND LIGHTS FILAMENTS. 3RD POSITION CLOSES CIRCUIT THROUGH STEP-UP TRANSFORMER FOR PLATE CIRCUIT.
3. OUTSIDE TERMINALS ON TUBE SIDE OF STEP DOWN TRANSFORMER TO BE USED WHEN NECESSARY TO OBTAIN THE PROPER FILAMENT VOLTAGE.
4. WARD-LEONARD 4^{ω} VITROHM RHEOSTAT PER KS-2266 (BOTH CONTACTS OPERATED BY SAME HANDLE.)
5. DISCONNECTING SWITCH ON CAN COVER (SWITCH IS OPENED WHEN COVER IS REMOVED.)

⊗ INDICATES BINDING POST TERMINALS ON REAR OF PANEL.

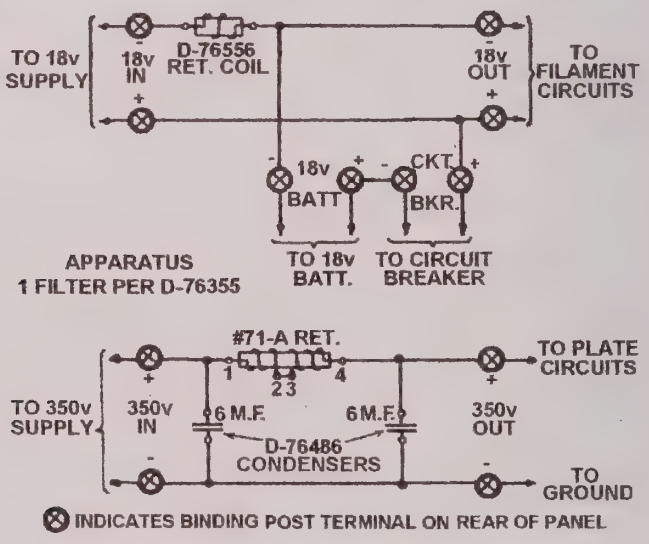
Drawing 197-B-12, 6-29-22 - Rectifier circuit for plate current supply in No. 1 system



Drawing 144-A-45, 6-29-22 - Rectifier panel - assembly

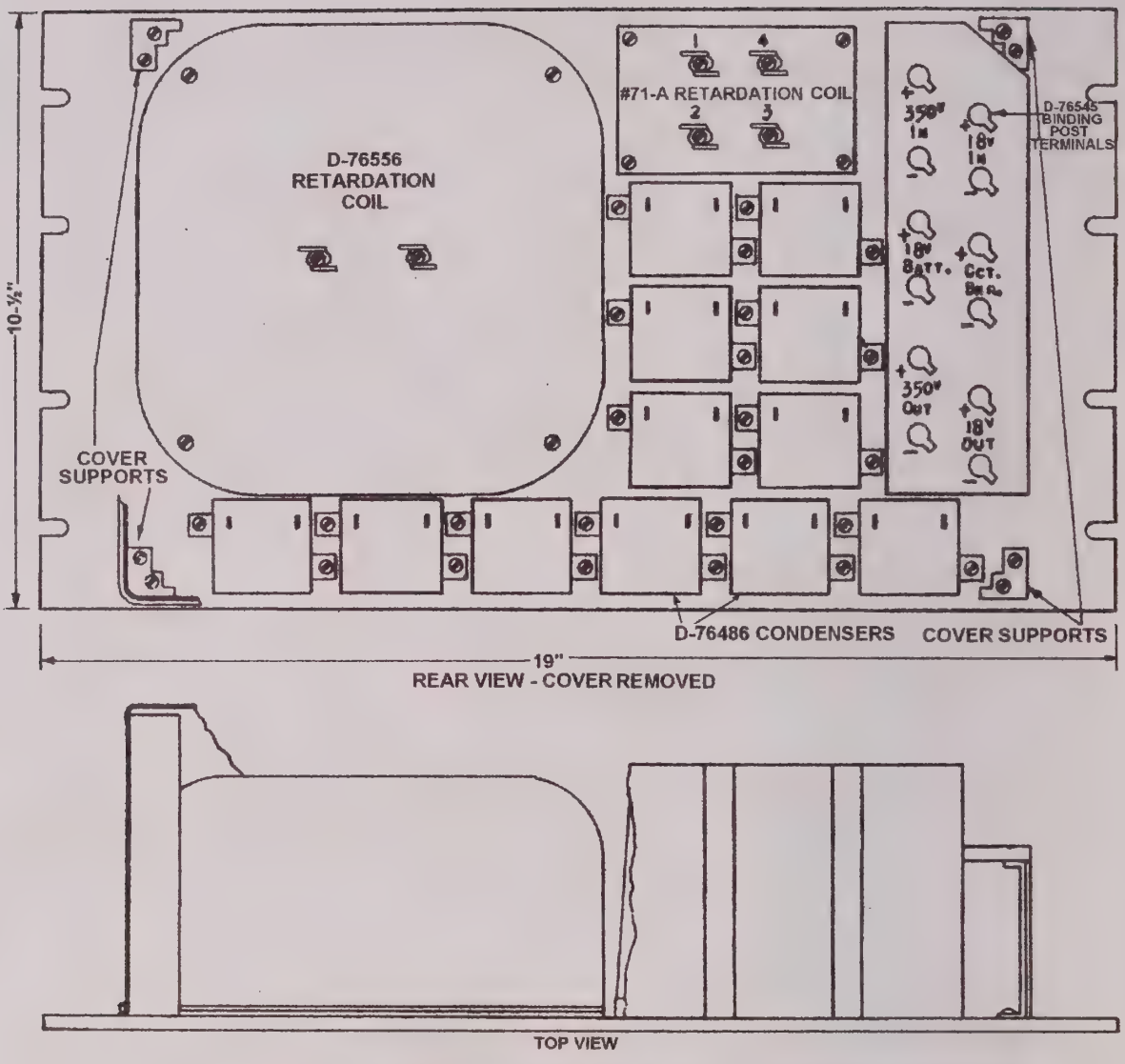


Drawing 197-B-13, 6-29-22 - Filter potentiometer circuit

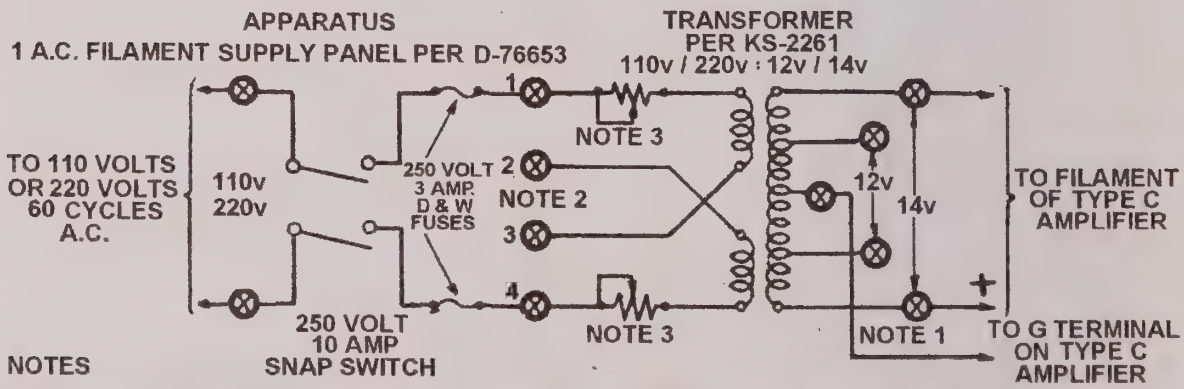


Drawing 197-B-45, 6-29-22 - Filter circuit for use with No. 2 system

Drawing 144-A-46, 6-29-22 - Filter-potentiometer panel - assembly



Drawing 197-B-15, 6-29-22 - Filter circuit - No. 2 system - assembly

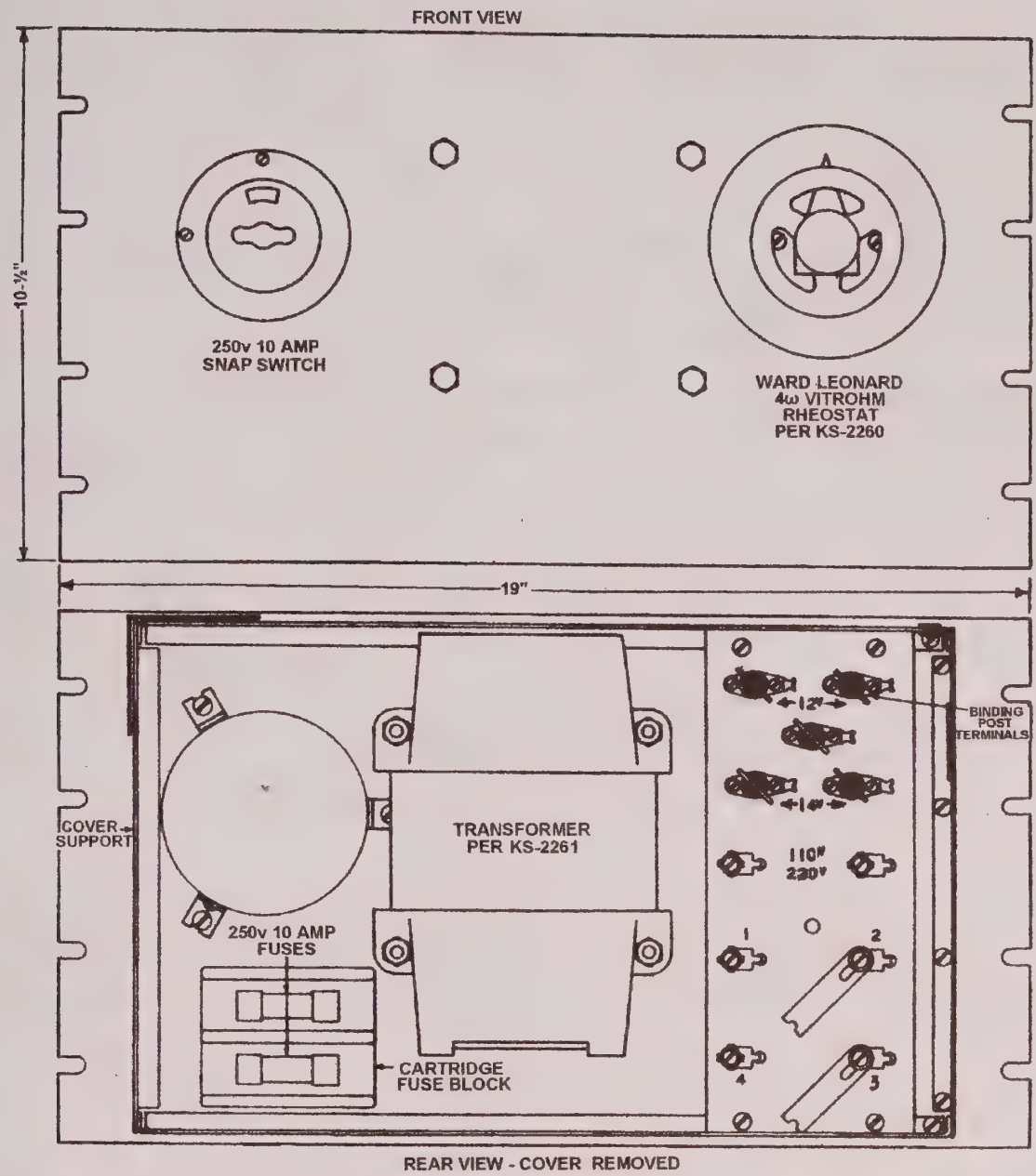


NOTES

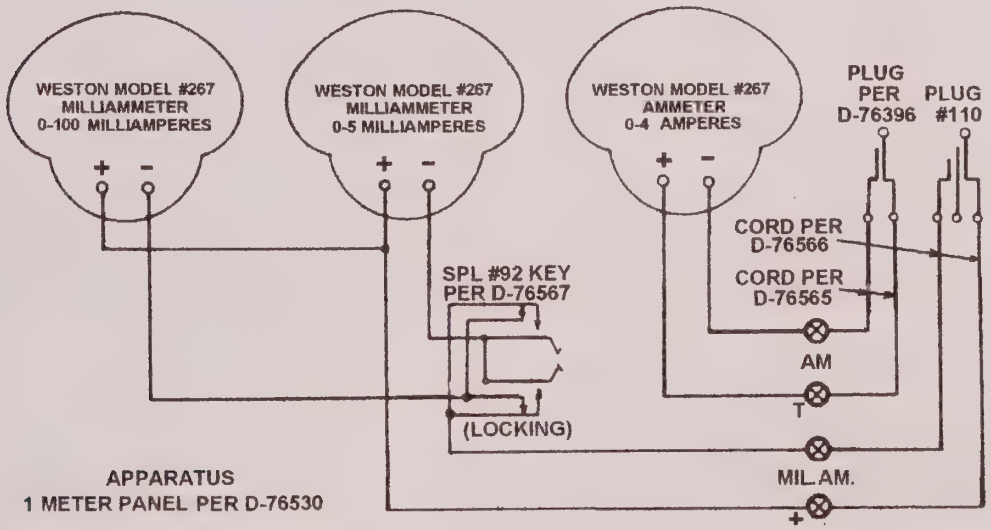
1. 12-VOLT OR 14-VOLT TAPS ON SECONDARY SIDE OF TRANSFORMER TO BE USED AS REQUIRED FOR OBTAINING THE PROPER FILAMENT CURRENT.
2. FOR 110-VOLT A.C. SUPPLY, STRAP TERMINALS 1 & 2, AND 3 & 4 TO CONNECT PRIMARY WIND- OF TRANSFORMER IN PARALLEL; FOR 220-VOLT A. C. SUPPLY STRAP TERMINALS 2 &3 TO CONNECT PRIMARY WINDINGS IN SERIES.
3. WARD LEONARD 4ω VITROHM RHEOSTAT PER KS-2260 (BOTH CONTACTS OPERATED BY SAME HANDLE.)

⊗ INDICATES BINDING POST TERMINAL ON REAR OF PANEL.

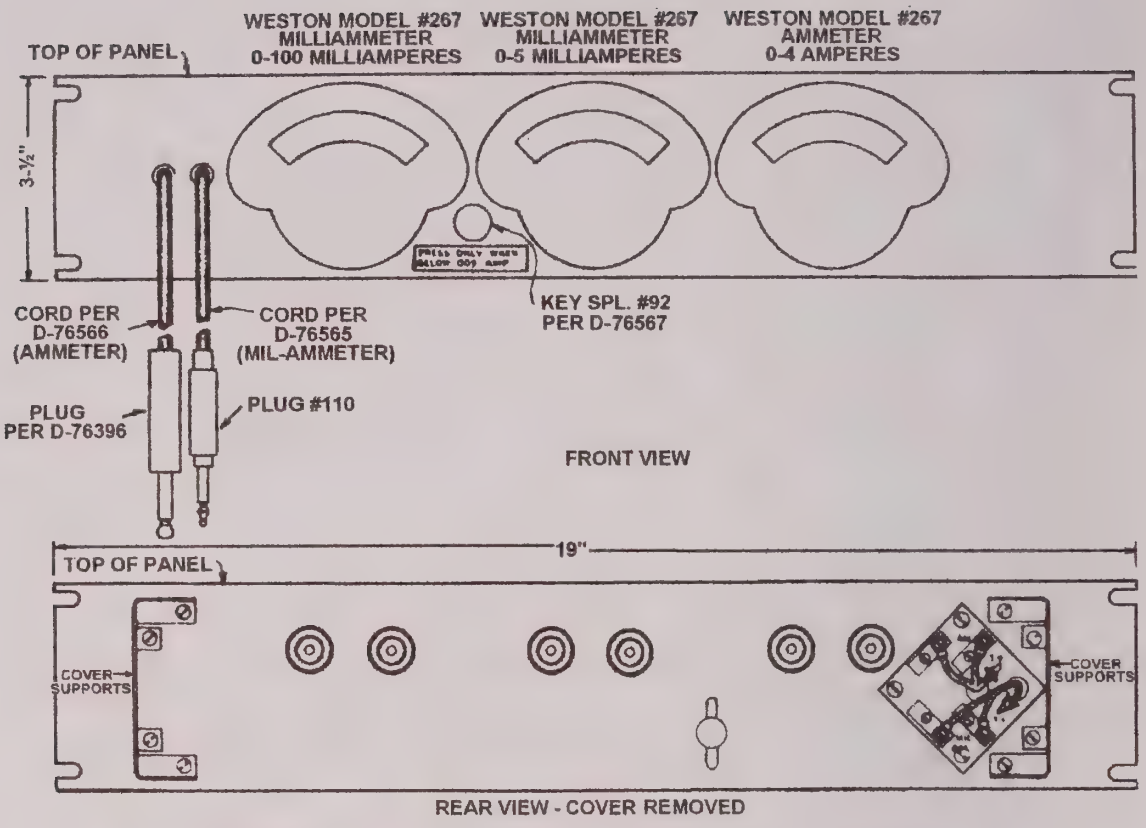
Drawing 197-B-16, 6-29-22 - Alternating current filament current-supply panel for type "C" amplifier



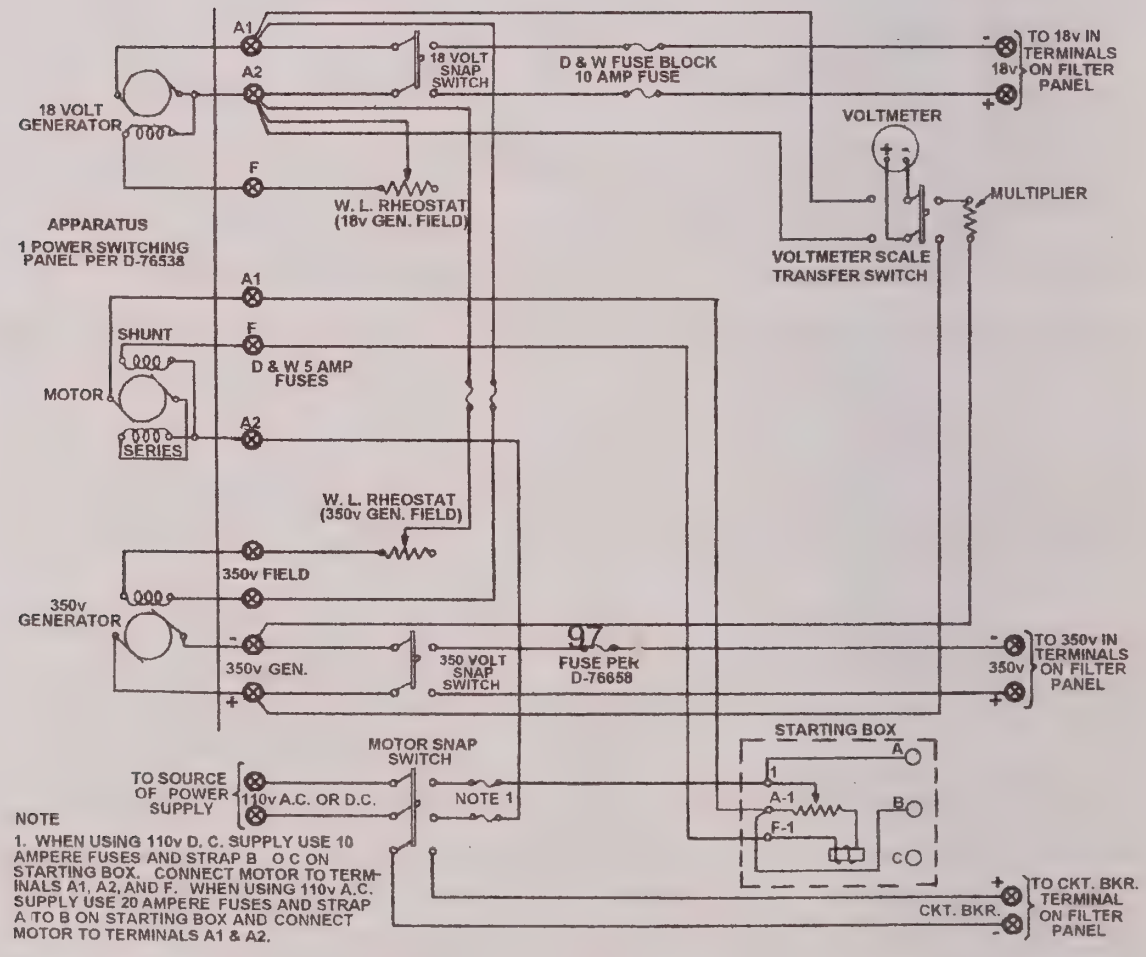
Drawing 197-B-17, 6-29-22 - Alternating-current filament-supply panel - assembly



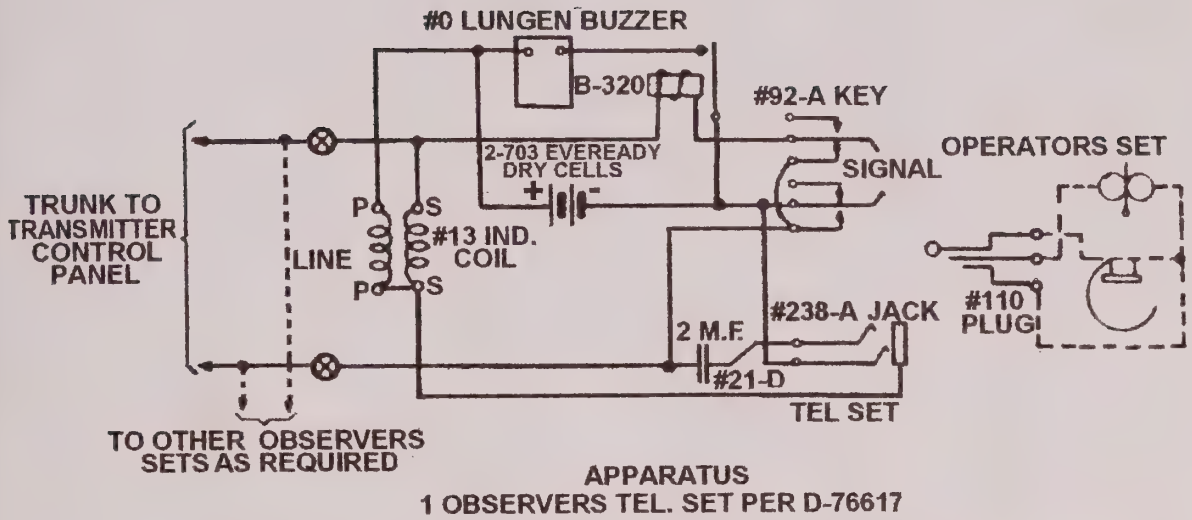
Drawing 197-B-18, 6-29-22 - Meter-panel circuit



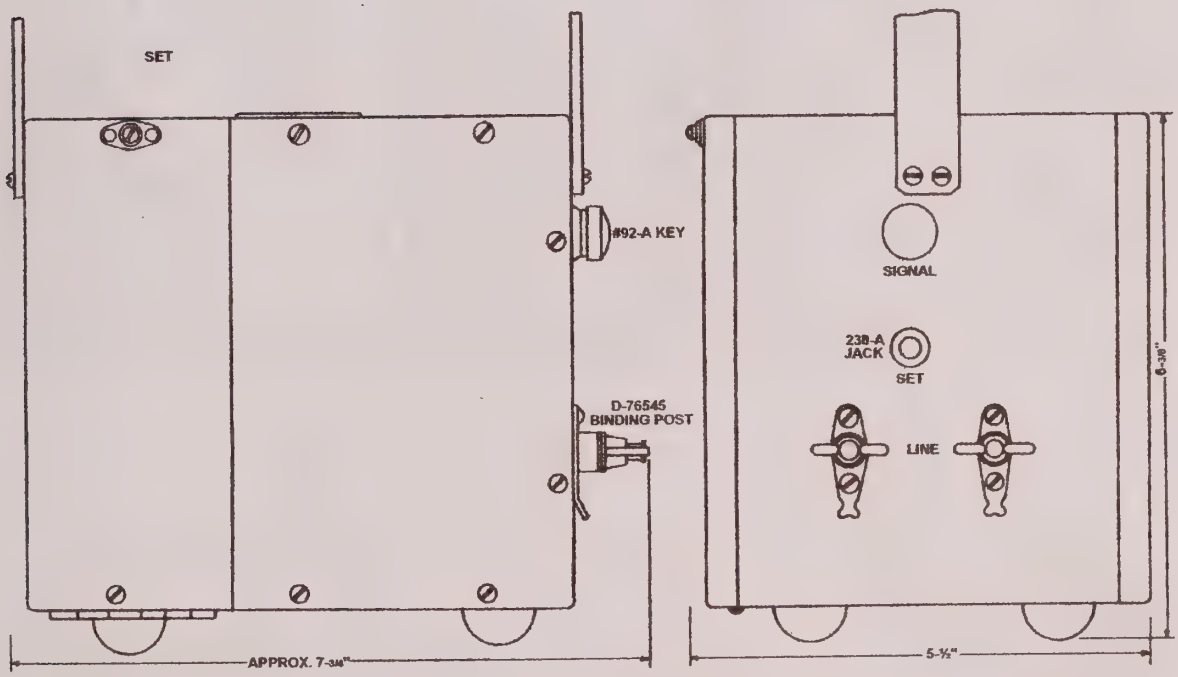
Drawing 197-B-19, 6-29-22 - Meter panel - assembly



Drawing 197-B-21, 7-8-22 - Power-switching circuit for motor-generator set

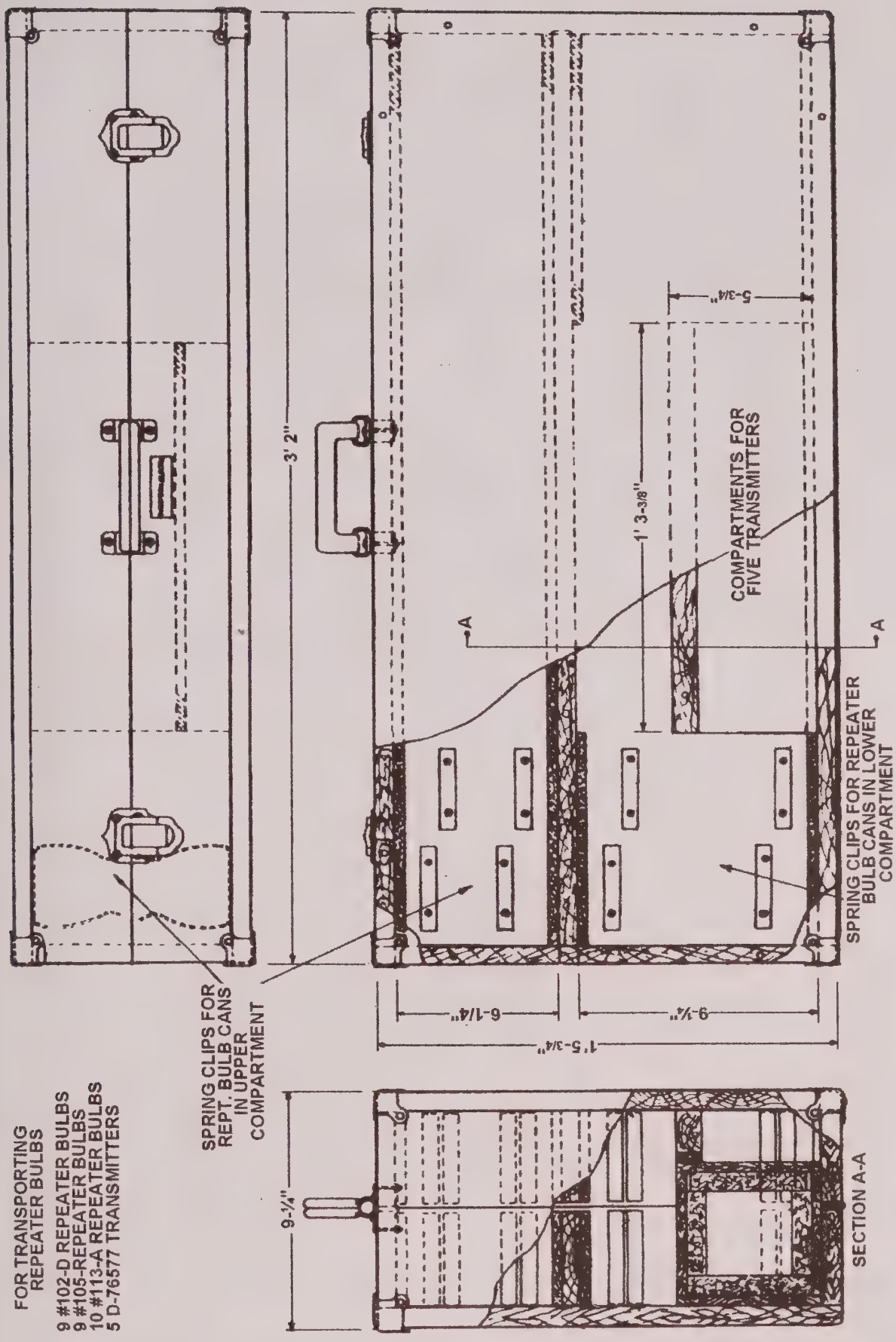


Drawing 197-B-20, 6-29-22 - Observer's telephone set

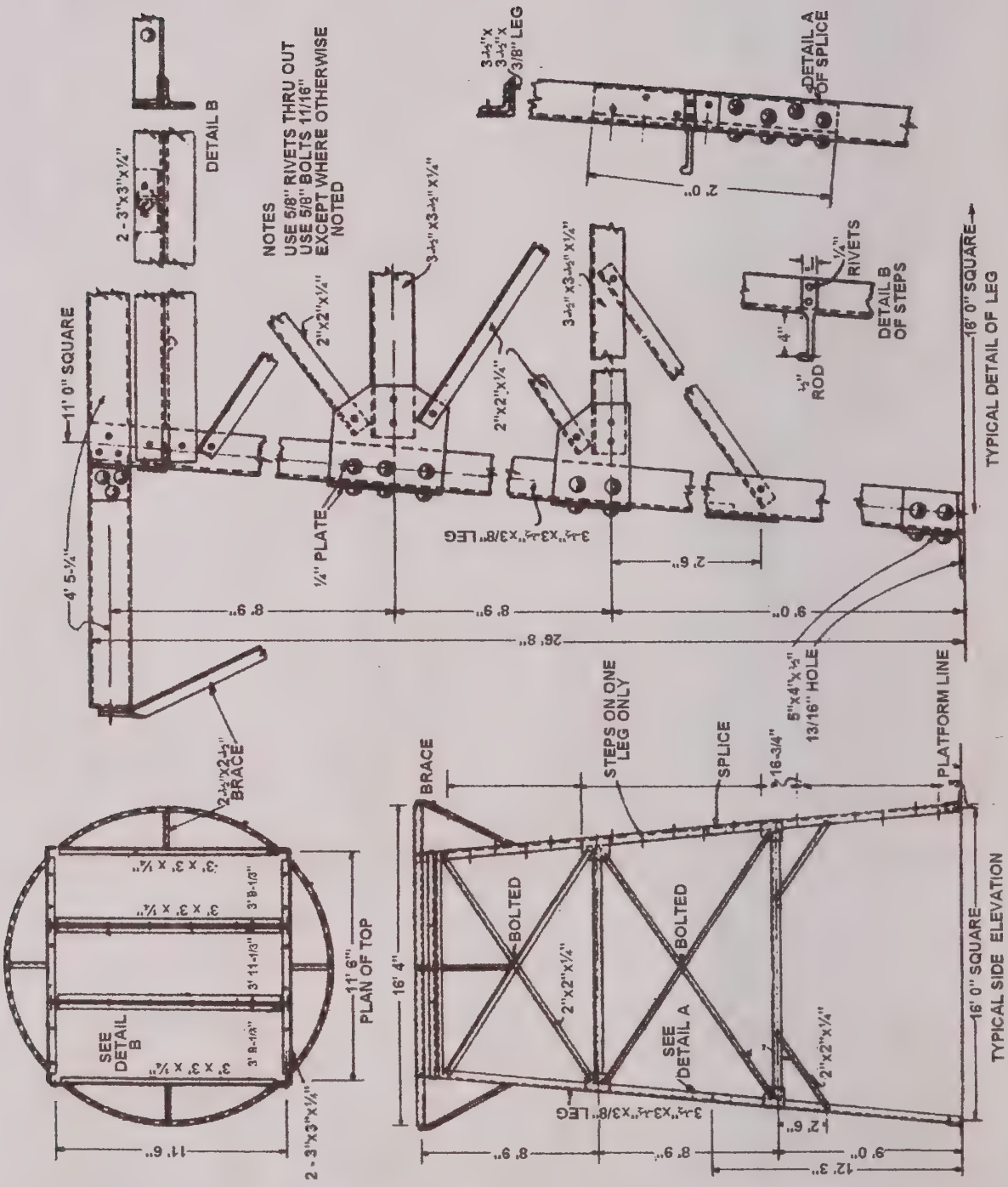


Drawing 197-B-30, 7-3-22 - Observer's telephone set D-76617 - assembly

Drawing 197-B-31, 7-3-22 - D-76634 carrying case - assembly



Drawing 144-A-52, 7-6-22 - D-76639 carrying case - assembly and details

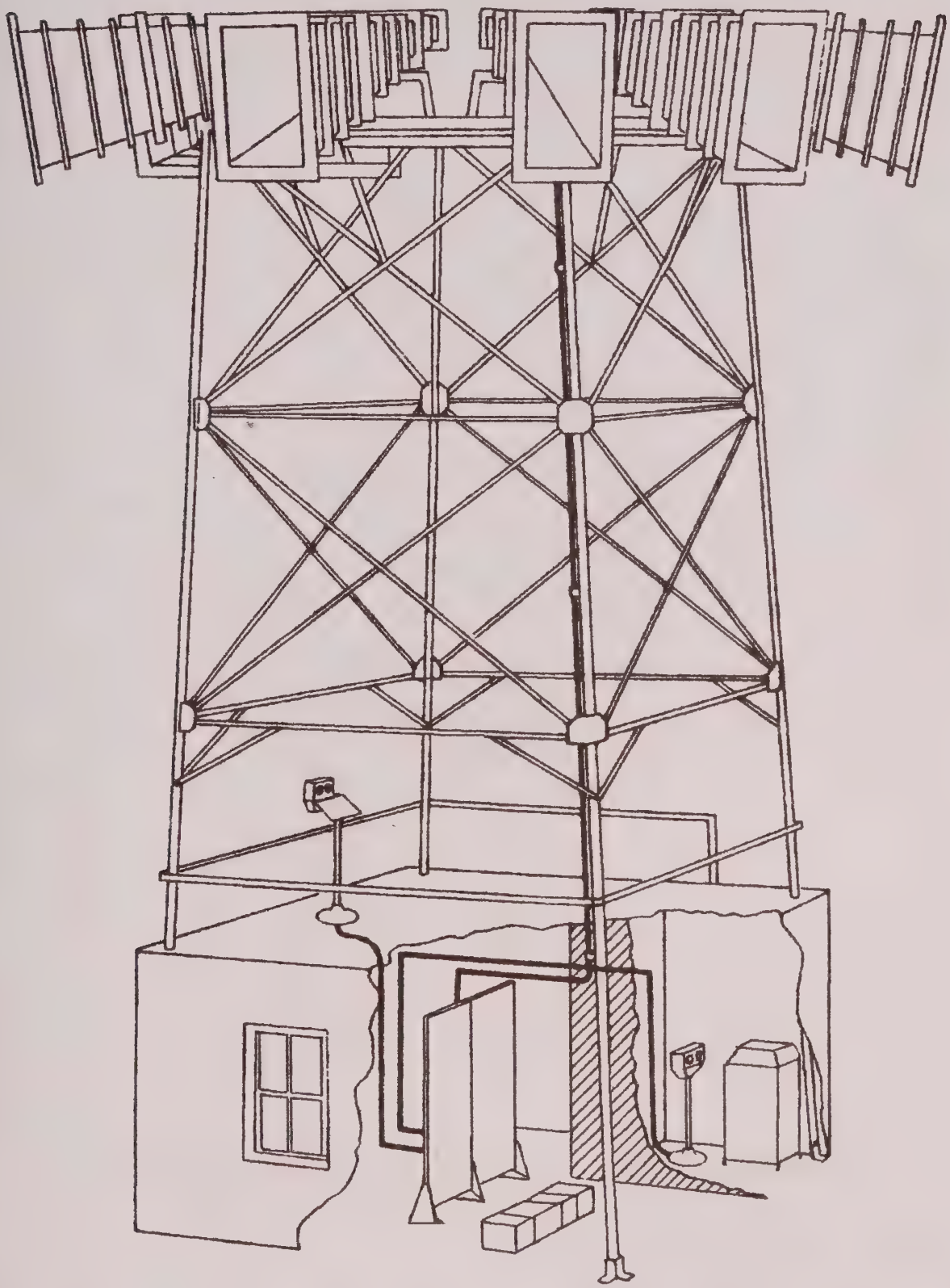


Drawing 144-A-64, 7-6-22 - Steel tower - for supporting horns used with voice amplifiers

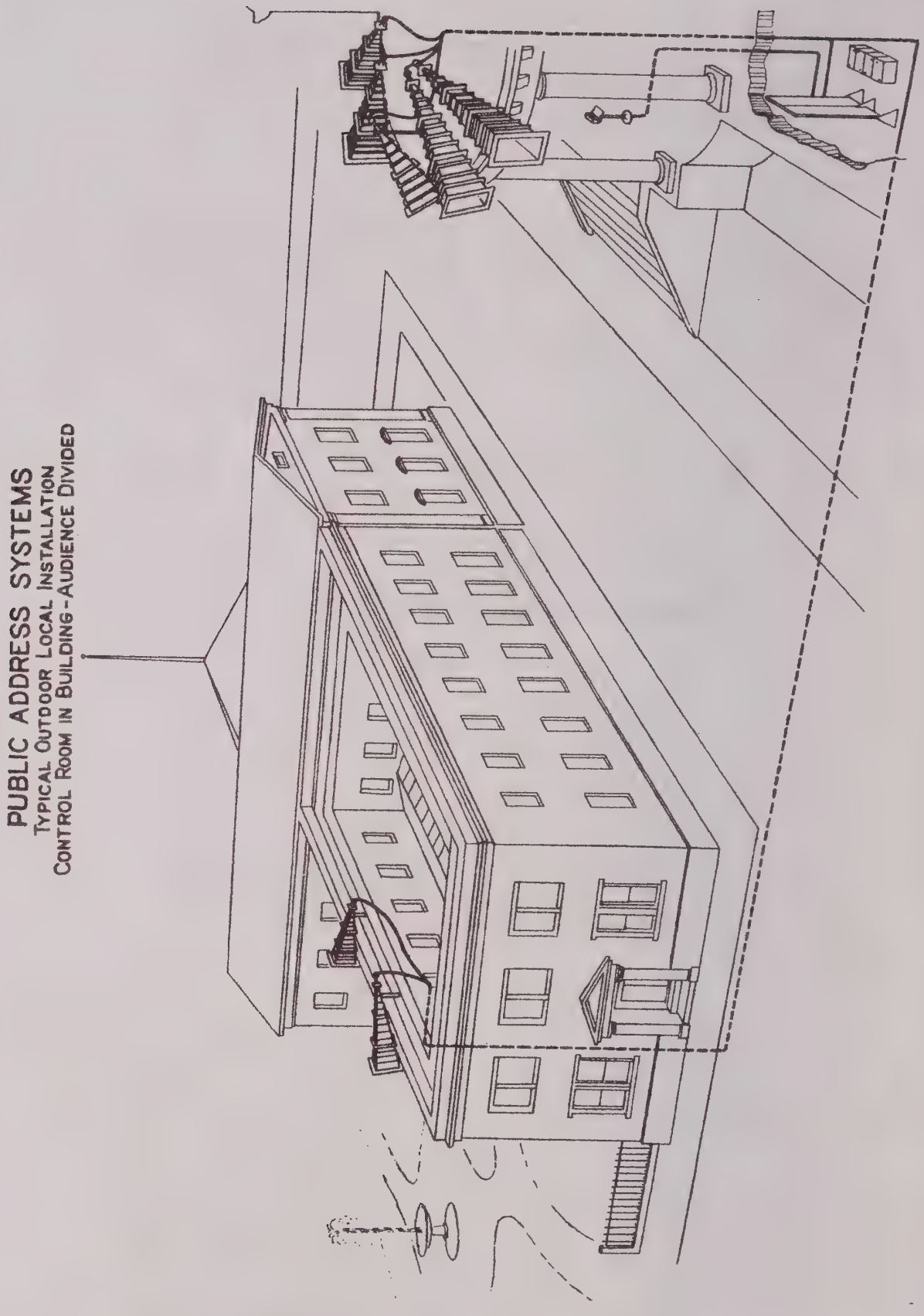
Drawing 144-A-53, 7-6-22 - Schematic - Outdoor local installations - close-talking

Drawing 144-A-54, 7-6-22 - Schematic - Outdoor local installations - distant-talking

PUBLIC ADDRESS SYSTEMS
TYPICAL OUTDOOR LOCAL INSTALLATION
CONTROL ROOM UNDER PLATFORM



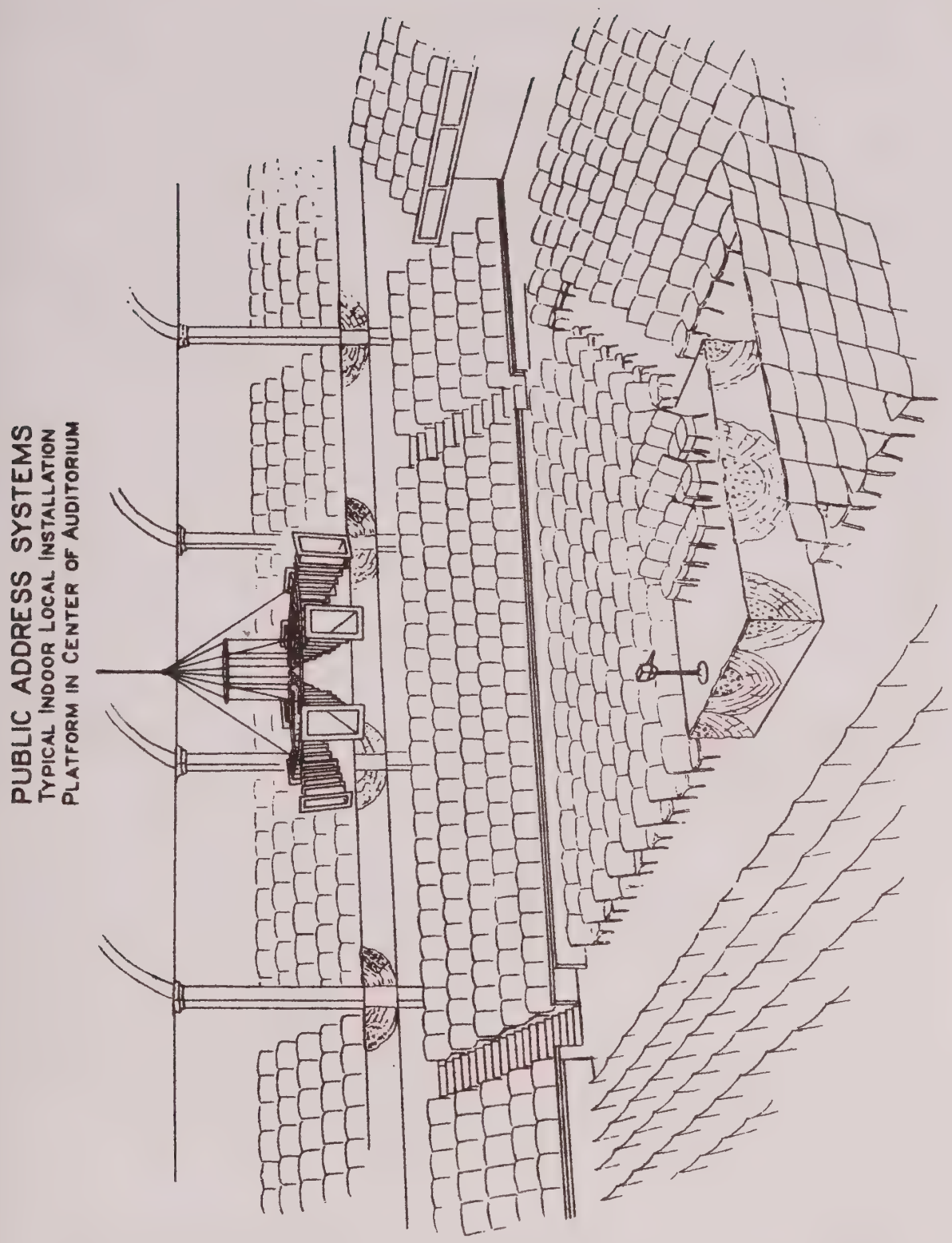
Drawing 144-A-55, 7-11-22 - Typical outdoor local installation - control room



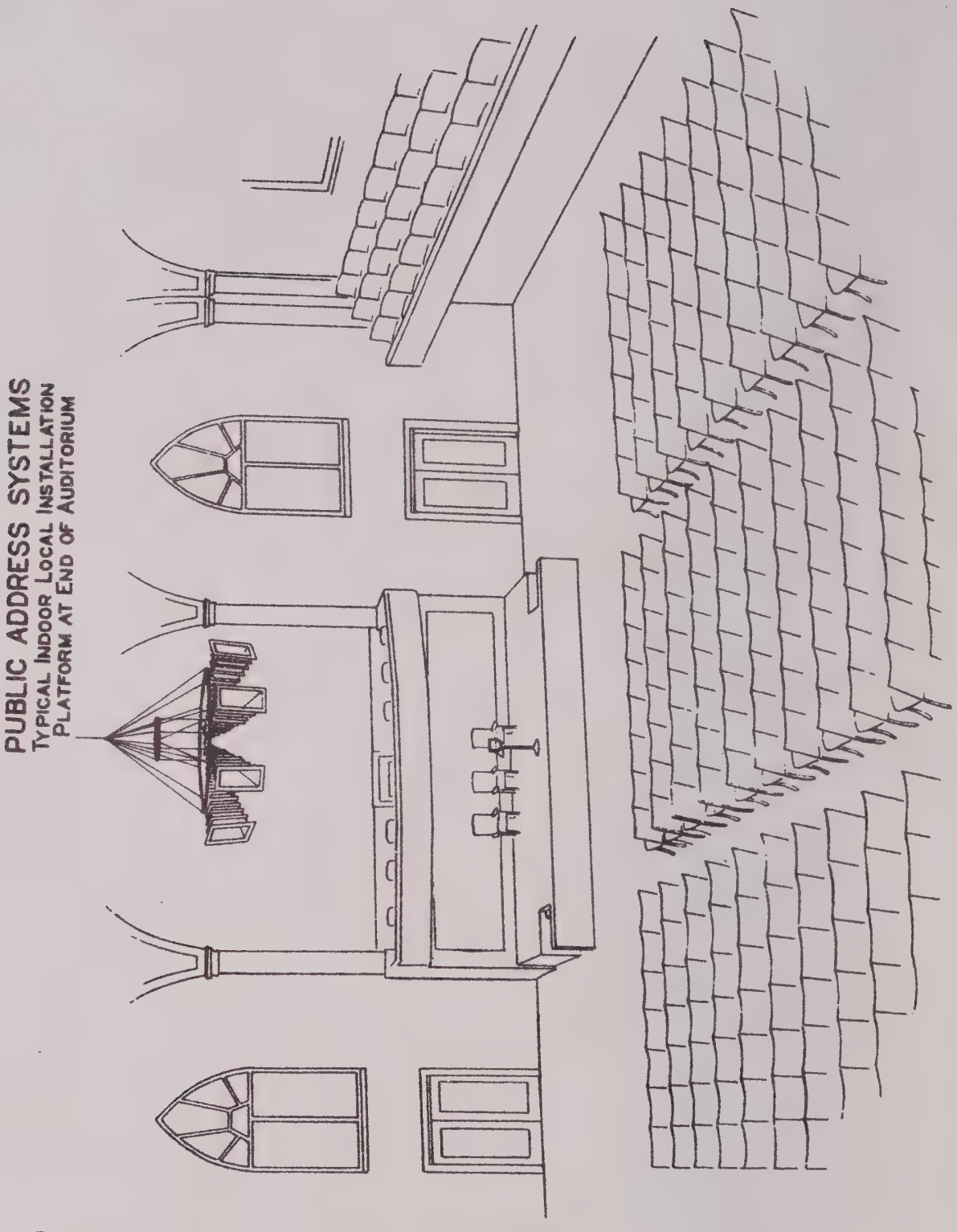
Drawing 144-A-56, 7-11-22 - Typical outdoor local installation - control room in building - audience divided

Drawing 144-A-57, 7-11-22 - Schematic - indoor local installations

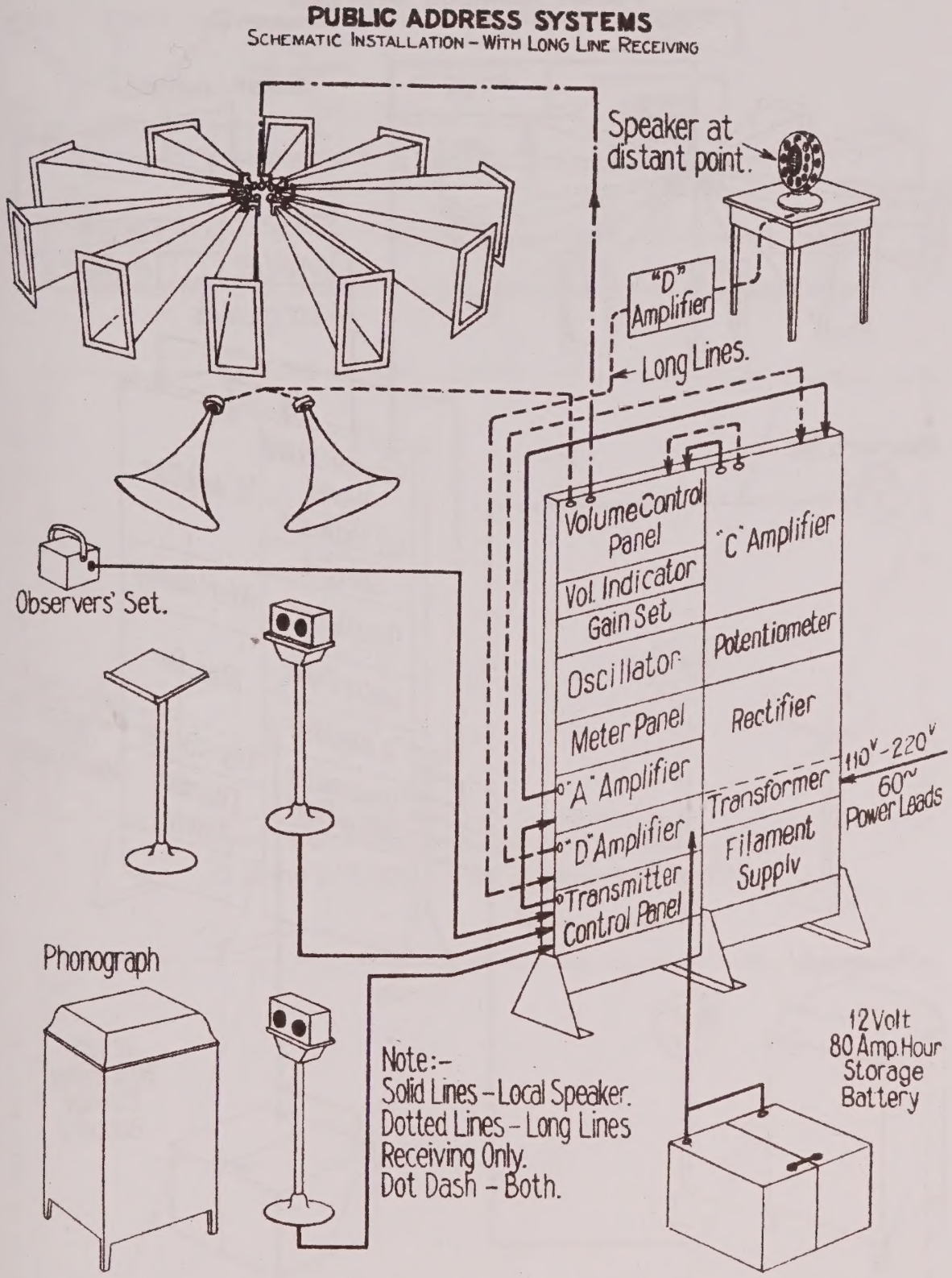
Drawing 144-A-58, 7-11-22 - Schematic - local installations - indoor and outdoor combined



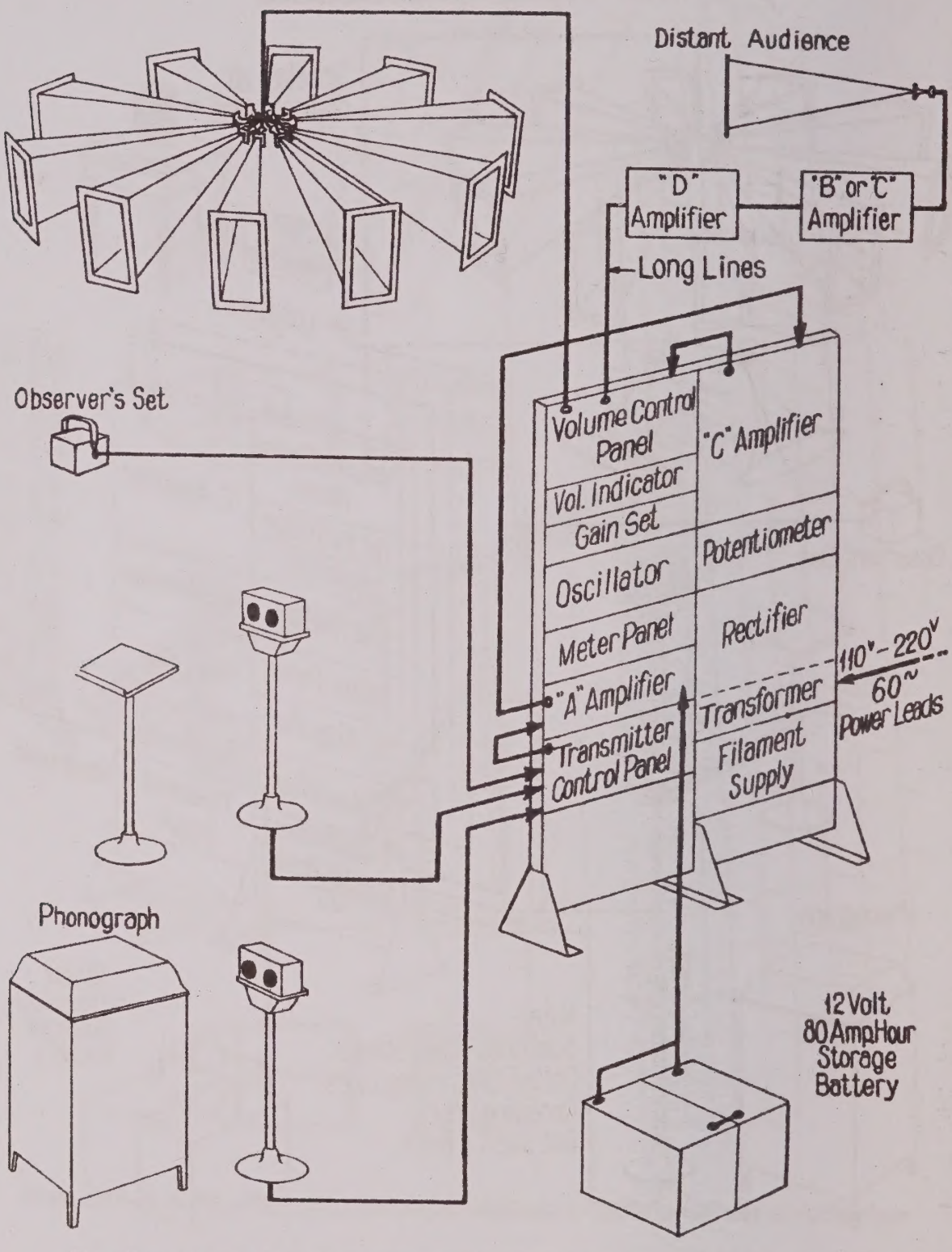
Drawing 144-A-59 - Typical indoor local installation - platform in center of auditorium



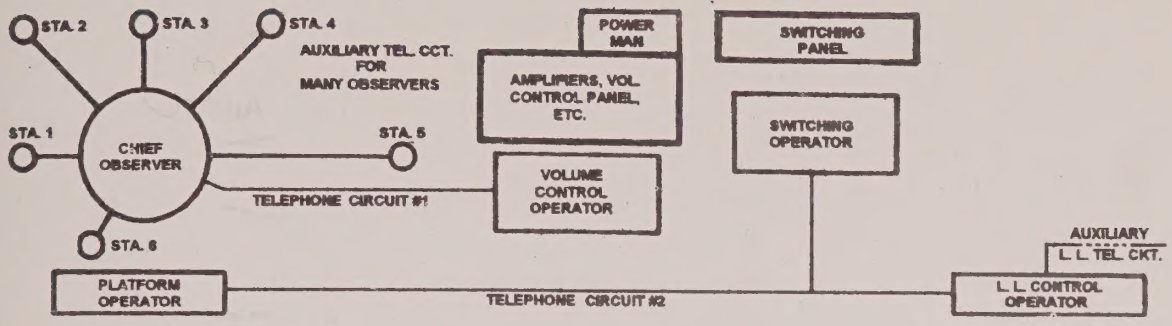
Drawing 144-A-60 - Typical indoor local installation - platform at end of auditorium



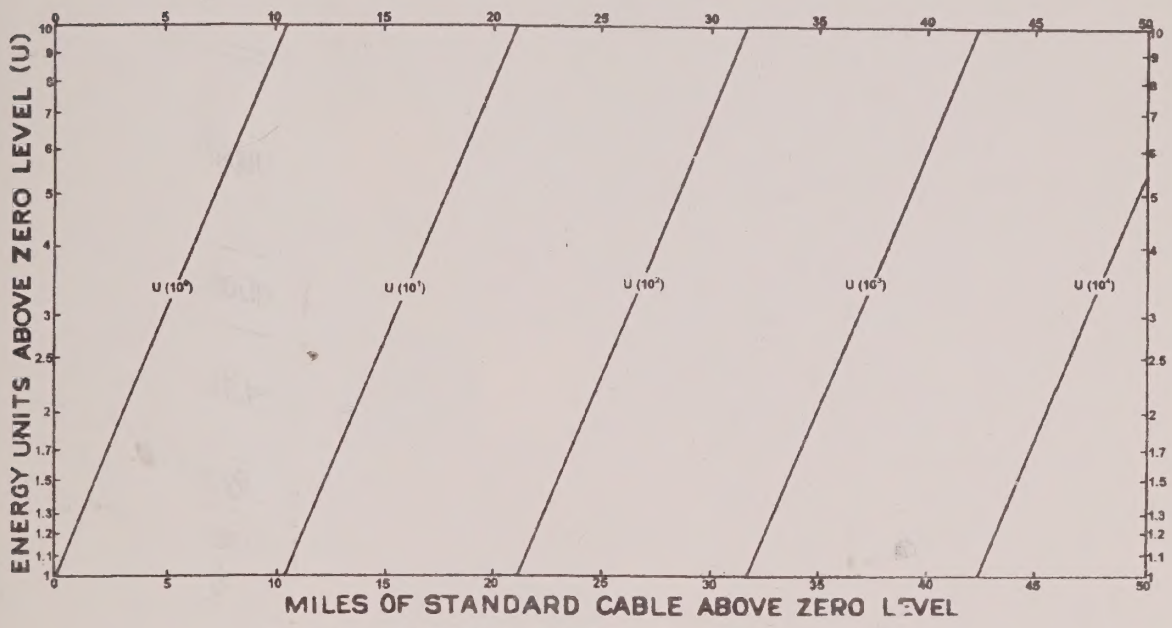
Drawing 144-A-61 - Schematic installation with long-line receiving



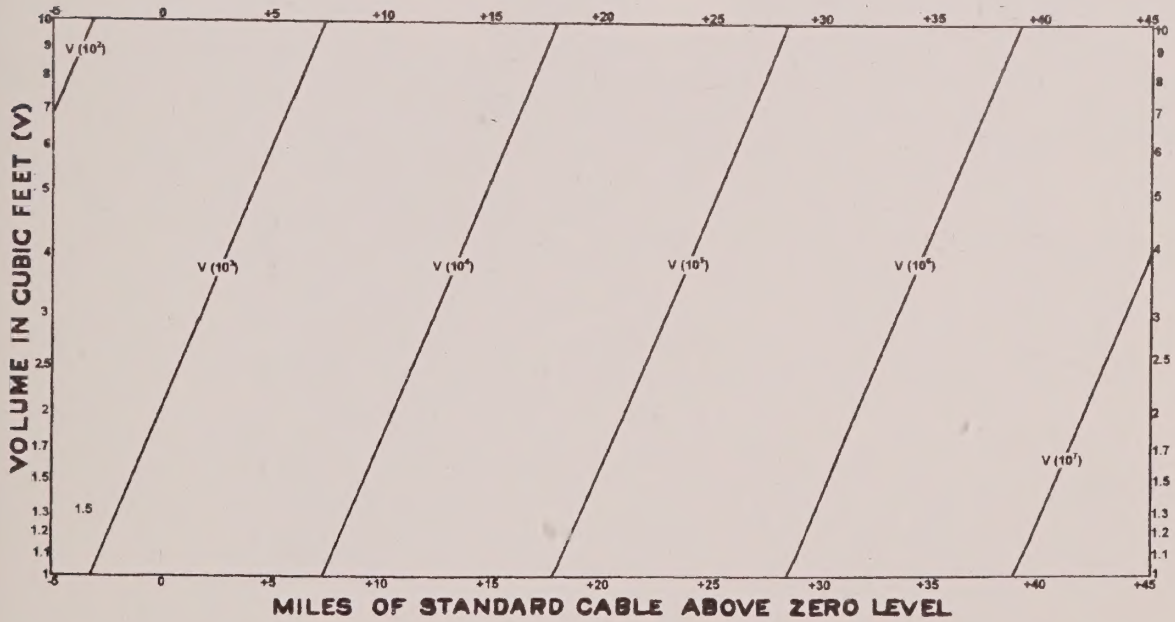
Drawing 144-A-62 - Schematic installation with long-line transmitting



Drawing 906-861, 6-30-22 - Organizational diagram of control forces



Drawing 910-305, 7-8-22 - Energy level chart



Drawing 910-306, 7-8-22 - Energy level required for indoor installations